ATTACHMENT 10

LINER CONSTRUCTION QA/QC DOCUMENTATION

ATTACHMENT 10

GUIDANCE DOCUMENTS FOR QUALITY ASSURANCE FOR THE INSTALLATION OF LINING SYSTEMS

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GUIDANCE DOCUMENTS FOR QUALITY ASSURANCE FOR THE INSTALLATION OF LINING SYSTEMS

GUIDANCE DOCUMENTS FOR QUALITY ASSURANCE FOR THE INSTALLATION OF LINING SYSTEMS

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Waste Management, Inc.
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Greg Frey
X00458

MEMO

DATE: April 21, 1993

TO: Distribution

FROM: Jim Urek
Lloyd Piper

SUBJECT: Lining Systems
Quality Assurance Manual

We are pleased to submit the 1993 Quality Assurance Manual for the Installation of Lining Systems (QAM) for your location's use. The QAM addresses the quality assurance of the installation of soil and geosynthetic materials used by Waste Management companies in their land disposal, surface impoundment and other waste containment facilities. The QAM is intended to serve as one component of the overall Quality Assurance Plan (QAP) developed for each project.

Project-specific addenda can be used to provide additions, deletions and changes necessary to the QAM sections used for a particular project. It is important to stress the need to develop project and site-specific QAPs based on this manual, and not to rely on the manual alone. This is particularly true for permitting documents, wherein you may be held to testing frequencies and intervals which are inappropriate for site conditions unless an addenda is developed.

In addition to the QAM, four guidance documents have been prepared discussing associated lining systems issues. These documents include a comparison of the 1993 QAM and the 1990 QAM, polyethylene material specifications, a procedure for defining a Soil Liner Acceptance Zone, and a Test Pad Program. These documents were prepared as separate documents from the QAM.

We appreciate all who have contributed to the development of the QAM and these guidance documents. We would especially like to thank Bob Pliska of Rust Environment and Infrastructure for his efforts in preparing these documents.

Please contact the Liner Task Force with any comments, questions or suggestions for improvements.

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QUALITY ASSURANCE MANUAL FOR THE INSTALLATION OF LINING SYSTEMS

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QUALITY ASSURANCE MANUAL FOR THE INSTALLATION OF LINING SYSTEMS

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1.0 GENERAL

1.1 SCOPE

This Quality Assurance Manual (QAM) addresses the quality assurance of the installation of soil and geosynthetic materials used in lining systems by Waste Management companies (Owner) for their land disposal, surface impoundment and other waste containment facilities. This QAM is applicable for lining systems which include base liner and final cover systems. Extreme care and detailed documentation are required in the selection and installation of all materials used in lining systems for waste containment applications.

This QAM primarily addresses quality assurance and is directed toward the Quality Assurance Consultant. In the context of this manual, quality assurance refers to means and actions employed by the Owner to assure conformity of the lining system production and installation with the project-specific Quality Assurance Plan (QAP), contractual and regulatory requirements. Quality control refers only to those actions taken to ensure that materials and workmanship meet the requirements of the project plans and specifications. Quality control is provided by the manufacturers, suppliers, contractors and installers of the various components of the lining system.

The QAM is one component of the overall QAP. A project-specific QAP is required for each project. At a minimum, the QAP shall consist of the following:

1. Pertinent Sections of this QAM or other applicable QAMs.

2. Project-Specific Addenda to the QAM Sections. Project-Specific Addenda shall be used to provide for additions, deletions, and changes necessary to the QAM Sections used for a particular project.

3. Project-Specific Plans and Specifications.

The QAP should contain all of the elements necessary to ensure that the project is constructed in accordance with project plans and specifications as well as regulatory requirements. This QAM serves as a foundation for a QAP, and is not a QAP in itself.

1.2 PARTIES

The parties discussed in this section are associated with the ownership, design, supply, manufacture, transportation, installation, and quality assurance of a lining system. The definitions, responsibilities, qualifications, and submittals of these parties are outlined in the following subsections.

1.2.1 Project Manager

1.2.1.1 *Definitions*

The Project Manager is the official representative of the Owner. In this manual, the term Project Manager shall apply equally to "Construction Coordinator", defined as the individual who coordinates construction and quality assurance activities for the project.

1.2.1.2 *Responsibilities*

The Project Manager is responsible for coordination of all construction quality assurance activities. The Project Manager is responsible for the organization and implementation of the QAP for the project as outlined in Section 1.1 of this manual. Other responsibilities include selection or approval of Earthwork Contractor, Geosynthetic Installer, Quality Assurance Consultant and the Quality Assurance Laboratory.

The Project Manager shall serve as communications coordinator for the project, initiating the resolution, pre-construction and construction meetings outlined in Section 1.3. As communications coordinator, the Project Manager shall serve as a liaison between all parties involved in the project to ensure that communications are maintained. The Project Manager shall also be responsible for proper resolution of all quality assurance issues that arise during construction.

1.2.1.3 *Qualifications*

The selection of the Project Manager is the direct responsibility of the Owner. Qualifications for this position include familiarity with the following:

1. Sections of this QAM or other applicable QAMs.

2. General earthwork construction techniques.

3. General geosynthetic installation techniques.

4. All applicable regulatory requirements.

5. Company policies and procedures for project management.

1.2.2 Designer

1.2.2.1 *Definitions*

The Designer is the individual and/or firm who prepares the design, including project plans and specifications for the lining system.

1.2.2.2 *Responsibilities*

The Designer is responsible for performing the engineering design and preparing the associated project plans and specifications for the lining system. The Designer is responsible for approving all design and specification changes and making design clarifications necessitated during construction of the lining system. Upon the request of the Project Manager, the Designer shall attend the resolution and pre-construction meetings outlined in Section 1.3 of this manual.

1.2.2.3 *Qualifications*

The Designer shall be a qualified engineer, certified or licensed as required by regulation. The Designer shall be familiar with the use of soils and/or geosynthetics including detailed design methods and procedures. In addition, the Designer should be familiar with applicable regulatory requirements.

1.2.2.4 *Submittals*

The Designer shall submit the project plans, specifications and associated engineering reports to the Project Manager. The Designer shall also submit completed design clarification forms to the Project Manager in a timely manner upon request. Other information may also be required by the Owner.

1.2.3 Manufacturer

1.2.3.1 *Definitions*

The Manufacturer is the firm which produces any of the various geosynthetic lining system components outlined in this QAM. In the case of a geocomposite, the Manufacturer is the firm which combines the components into the final product.

1.2.3.2 *Responsibilities*

Each Manufacturer is responsible for the production of its geosynthetic product. In addition, each Manufacturer is responsible for the condition of the geosynthetic product until the material is accepted by the Project Manager upon delivery. Each Manufacturer shall produce a consistent product that meets the project specifications. Each Manufacturer shall provide quality control documentation for its product as specified in this QAM.

1.2.3.3 *Qualifications*

Each Manufacturer shall:

1. Be pre-qualified and approved by the Owner.

2. Provide sufficient production capacity and qualified personnel to meet the demands of the project.

3. Have an internal quality control program for its product that meets the requirements presented in this QAM.

1.2.3.4 *Submittals*

Pre-qualification: At a minimum, the Manufacturer shall meet the following requirements and submit the following information to the Project Manager to be considered for pre-qualification:

1. Corporate background and information.

2. Manufacturing capabilities:

   a. Information on plant size, equipment, personnel, number of shifts per day, and capacity per shift.
   b. Daily production quantity of the specified product available for the Owner's facilities.
   c. A list of material properties including certified test results with attached geosynthetic samples.
   d. A list of at least 15 completed landfill or surface impoundment facilities totalling a minimum of 15,000,000 ft^2 (1,500,000 m^2), for which the Manufacturer has manufactured a geosynthetic. For each facility, the following information shall be provided:

      (1) Name and purpose of facility, its location and date of installation.
      (2) Name of Owner, Project Manager, Designer, Installer and Fabricator (if any).
      (3) Type of geosynthetic and surface area of geosynthetic manufactured.
      (4) Available information on the performance of the lining system.

3. The Manufacturer's quality control manual, including a description of the quality control laboratory facilities.

4. The origin (supplier's name and production plant) and identification (brand name and number) of resin used to manufacture the product.

Additional information may need to be submitted if requested by the Project Manager.

Pre-installation: Prior to the installation of any geosynthetic material, the Manufacturer shall submit to the Project Manager all quality control documentation required by the appropriate section of this QAM. This documentation shall be reviewed by the Geosynthetic Quality Assurance Consultant as outlined in Section 1.2.7 of this QAM before installation can begin.

1.2.4 Earthwork Contractor

1.2.4.1 *Definitions*

The Earthwork Contractor is the firm which performs the site earthwork preparation and construction of the soil components of the lining system. The Earthwork Superintendent is the

individual responsible for the Earthwork Contractor's field crew. The Earthwork Superintendent represents the Earthwork Contractor at all site meetings and acts as the Earthwork Contractor's spokesman on the project.

1.2.4.2 *Responsibilities*

The Earthwork Contractor is responsible for constructing soil components of the lining systems in conformance to the project plan and specifications. The Earthwork Contractor may also be responsible for locating and transporting the required earth and granular materials, concrete, piping, and other work, as outlined in the project specifications.

1.2.4.3 *Qualifications*

The Earthwork Contractor shall be:

1. Pre-qualified and approved by the Owner.

2. Able to provide qualified personnel to meet the demands of the project.

At a minimum, the Earthwork Contractor shall provide a Superintendent as described below.

The Superintendent must be qualified based on previously demonstrated experience, management ability, and authority. The Superintendent shall be approved by the Project Manager.

1.2.4.4 *Submittals*

Pre-qualification: At a minimum, the Earthwork Contractor shall meet the following requirements and submit the following information to the Project Manager to be considered for prequalification:

1. Company background and information

2. Demonstration of bonding capability

3. List of outstanding contracts

4. List of readily available equipment required to perform the work (i.e., scrapers, graders, scarifiers, compactors, disking equipment, water trucks, and admixing equipment, if required)

5. List of at least five comparable projects with the following information for each project:

   a. Name of the facility, its location, date of installation.
   b. Name of project manager or contact person for the installation.
   c. Description and purpose of installation and definition of contractor's scope of work.

Additional information may need to be submitted if requested by the Project Manager.

Pre-installation: Prior to commencement of the earthwork activities, the Earthwork Contractor shall submit to the Project Manager:

1. Resume of the Earthwork Superintendent to be assigned to this project, including the dates and duration of employment.

2. Schedule of construction activities.

3. List of specific equipment and personnel to be used on the project.

Installation: During the installation, the Earthwork Contractor shall submit to the Project Manager:

1. Subgrade acceptance certificates for each area to be covered by the lining system signed by the Earthwork Contractor.

Completion: Upon completion of the installation, the Earthwork Contractor shall submit a Certificate of Completion.

1.2.5 Geosynthetic Installer

1.2.5.1 *Definitions*

The Geosynthetic Installer (Installer) is the firm which installs the geosynthetic components of the lining system. The Geosynthetic Superintendent is the individual responsible for the Installer's field crew. The Geosynthetic Superintendent shall represent the Installer at all site meetings and act as the Installer's spokesman on the project. The Master Seamer shall be an experienced seamer on the Installer's field crew who shall provide direct supervision over less experienced seamers.

1.2.5.2 *Responsibilities*

The Installer is responsible for field handling, storing, deploying, seaming, temporary restraining and all other aspects of the geosynthetics installation. The Installer may also be responsible for transportation of these materials to the site and for anchor systems, if required by the project specifications. The Installer shall be responsible for submittal of the documentation listed in Section 1.2.5.4.

1.2.5.3 *Qualifications*

The Installer shall be pre-qualified and approved by the Owner. The Installer shall be able to provide qualified personnel to meet the demands of the project. At a minimum, the Installer shall provide a Geosynthetic Superintendent and a Master Seamer.

The Geosynthetic Superintendent shall be qualified based on previously demonstrated experience, management ability and authority. The Geosynthetic Superintendent shall be approved by the Project Manager.

For geomembrane installation, all personnel performing seaming operations shall be qualified by experience or by successfully passing seaming tests. The Master Seamer shall have experience seaming and approved by the Project Manager.

1.2.5.4 *Submittals*

Pre-qualification: At a minimum, the Installer shall submit the following information to the Project Manager to be considered for pre-qualification:

1. Corporate background and information

2. Description of installation capabilities:

   a. Information on equipment (numbers and types), and personnel (number of Superintendents, number of crews).
   b. Average daily production anticipated.
   c. Samples of field geomembrane seams and a list of minimum values for geomembrane seam properties.

3. A list of at least ten completed facilities, totalling a minimum of 2,000,000 ft^2 (200,000 m^2) for which the Installer has installed geosynthetics. For each installation, the following information shall be provided:

   a. Name and purpose of facility, its location, and date of installation.
   b. Name of owner, project manager, designer, manufacturer, fabricator (if any), and name of contact at the facility who can discuss the project.
   c. Name and qualifications of the Superintendent(s) of the Installer's crew(s).
   d. Type of geosynthetic, and surface area installed.
   e. Type of seaming and type of seaming apparatus used.
   f. Duration of installation.
   g. Available information on the performance of the lining system.

4. The Installer's quality control manual.

5. A copy of a letter of recommendation supplied by the geomembrane manufacturer.

Pre-installation: Prior to commencement of the installation, the Installer must submit to the Project Manager:

1. Resume of the Geosynthetic Superintendent to be assigned to this project, including dates and duration of employment.

2. Resume of the Master Seamer to be assigned to this project, including dates and duration of employment.

3. A panel layout drawing showing the installation layout identifying field seams as well as any variance or additional details which deviate from the project plans or specifications. The layout shall be adequate for use as a construction plan and shall include dimensions and details as appropriate.

4. Installation schedule.

5. A list of personnel performing field seaming operations along with pertinent experience information.

6. All geosynthetic quality control certificates as required by this QAM, unless submitted directly to the Project Manager by the Manufacturer.

7. Certification that extrudate to be used is comprised of the same resin as the geomembrane to be used.

This documentation shall be reviewed by the Geosynthetic Quality Assurance Consultant before installation of the geosynthetic can begin.

Installation: During installation, the Installer shall be responsible for the submission of:

1. Quality control documentation recorded during installation.

2. Subgrade surface acceptance certificates signed by the Installer for each area to be covered by the lining system.

Completion: Upon completion of the installation, the Installer shall submit:

1. The warranty obtained from the Manufacturer.

2. The installation warranty.

1.2.6 Soil Quality Assurance Consultant

1.2.6.1 *Definitions*

The Soil Quality Assurance Consultant (Soil QAC) is the firm which observes and documents activities related to the quality assurance of the installation of the soil components of the lining system on behalf of the Owner. The Soil QAC and Geosynthetic QAC may be the same party.

In this QAM, the term Soil Quality Assurance Engineer (Soil QAE) refers to the engineer employed by the QAC who is personally in charge of the quality assurance work. In some cases, the duties of the Soil QAE may be shared by two individuals: a Soil Quality Assurance

Certifying Engineer and a Soil Quality Assurance Resident Engineer. Although not located at the site, the Soil Quality Assurance Certifying Engineer shall visit the site often enough to be familiar with the details of the project. The Soil Quality Assurance Certifying Engineer may also be known as the Soil Quality Assurance Officer.

The personnel of the Soil QAC also include Soil Quality Assurance Monitors (Soil QA Monitors) who are located at the site for construction observation and documentation.

1.2.6.2 *Responsibilities*

The Soil QAC is responsible for observing and documenting activities related to the quality assurance of the construction of the soil components of the lining systems. The Soil QAC is responsible for the implementation of the project QAP prepared by the Project Manager. The Soil QAC is also responsible for issuing a final Quality Assurance Report, sealed by a licensed Professional Engineer, as outlined in Section 2.0 of this QAM. Other duties of the Soil QAC shall include overseeing the soil laboratory testing.

The specific duties of the Soil QAC personnel are as follows:

1. The Soil QAE:

   a. Reviews all project plans and specifications.
   b. Reviews other site-specific documentation.
   c. Develops site-specific addenda for quality assurance of soil components with the assistance of the Project Manager as necessary.
   d. Administers the soil portions of the QAP, including assigning and managing all soil quality assurance personnel, reviews all field reports, and provides engineering review of all quality assurance related issues.
   e. Familiarizes himself with all applicable changes to project plans and specifications as issued by the Designer.
   f. Acts as on-site (resident) representative of the Soil QAC.
   g. Familiarizes all Soil QA Monitors with the site and the project QAP.
   h. Assigns Soil QA Monitors to observe and document all activities requiring monitoring.
   i. Attends all quality assurance related meetings, including resolution, pre-construction, daily, weekly meetings.
   j. Reviews the Earthwork Contractor's personnel qualifications for conformance with those qualifications preapproved for work on-site.
   k. Reviews the calibration certification of the on-site and off-site soil testing equipment.
   l. Manages the preparation of the record drawings.
   m. Reviews the Soil QA Monitors' daily reports, logs, and photographs.
   n. Notes any on-site activities that could result in damage to the installed soil components.
   o. Reports to the Project Manager, and logs in the daily report, any relevant observations reported by the Soil QA Monitors.
   p. Prepares his own daily report.
   q. Prepares a daily summary of the soil component quantities estimates installed each day of construction activity.

r. Prepares a weekly summary of soil quality assurance activities at the end of each week of the construction activity.
s. Oversees marking, packaging and shipping of all laboratory test samples.
t. Reviews the results of laboratory testing and makes appropriate recommendations.
u. Recommends the approval of the final soils acceptance to the Project Manager.
v. Designates a Soil QA Monitor to represent the QAE whenever he is absent from the site while operations are ongoing.
w. Reports any unapproved deviations from the QAP to the Project Manager.
x. Maintains field files of all logs and reports.
y. Maintains qualifications of all personnel and calibration of equipment.
z. Prepares the final Quality Assurance Report.

2. The Soil QA Monitor:

a. Monitors, logs, photographs and/or documents all soil component installation operations. Photographs shall be taken routinely and in critical areas of the installation sequence. These duties shall be assigned by the Soil QAE.
b. Monitors and documents the following operations for all soil components:
   (1) Material delivery
   (2) Unloading and on-site transport and storage
   (3) Sampling and conformance testing
   (4) Deployment operations
   (5) Condition of the soil components as placed
   (6) Visual observation, by walkover, of the finished soil components
   (7) Sampling and field testing of the finished soil components
   (8) Repair operations, if and when necessary
c. Conducts soil sampling and testing.
d. Documents any on-site activities that could result in damage to the constructed soil components. Any problems noted shall be reported as soon as possible to the Soil QAE.

Any differences of the Soil QAC's interpretation of the project plans and specifications from the Earthwork Contractor's interpretation shall be properly and adequately assessed by the Soil QAC through discussion with the Earthwork Contractor. If such assessment indicates any actual or suspected work deficiencies, the Soil QAC shall inform the Earthwork Contractor of these deficiency issues.

1.2.6.3 *Qualifications*

The Soil QAC shall be pre-qualified and approved by the Owner. The Soil QAC shall be experienced in the preparation of quality assurance documentation including quality assurance forms, reports, certifications and manuals.

The Soil QAE shall hold a B.S., M.S., or Ph.D degree in civil engineering or related fields and be licensed as a Professional Engineer. If the duties of the Soil QAE are shared by two parties, only the Soil Quality Assurance Certifying Engineer shall be required to be a licensed

Professional Engineer. The Soil QAE shall be specifically experienced in the installation of soil liners and shall have the necessary training and certification by the Soil QAC in the duties of a Soil QAE. The Soil QAE shall be approved by the Project Manager.

Soil QA Monitors shall have specific training in construction quality assurance of engineered soil structures and be so designated by the Soil QAE. The Monitors shall be approved by the Project Manager.

1.2.6.4 ***Submittals***

Pre-qualification: At a minimum, the Soil QAC shall submit the following information in writing to the Project Manager to be considered for pre-qualification:

1. Corporate background and information:

    a. General company information
    b. Proof of insurance
        (1) Professional liability
        (2) "Umbrella" coverage
        (3) Other coverages as required by statute and/or proposed contractual agreement

2. Quality assurance capabilities:

    a. A summary of the firm's experience in quality assurance, specifically quality assurance of soil components of lining systems.
    b. A summary of quality assurance documentation and methods used by the firm, including sample quality assurance forms, reports, certifications, and manuals prepared by the firm.
    c. Resumes of key personnel.

Additional information may need to be submitted if required by the Project Manager.

Pre-construction: Prior to beginning work on a project, the Soil QAC shall, in writing, provide the Project Manager with the following:

1. Resumes of personnel to be involved in the project including Soil QAE and Soil Quality Assurance Monitors.
2. Proof of professional engineering registration in the appropriate state of the engineer to be designated as the Soil Quality Assurance Certifying Engineer, as well as proof of B.S., M.S. or Ph.D in civil engineering or related field degree.
3. Proof of the required soil components quality assurance experience of all of the quality assurance personnel.
4. Examples of forms to be used in documentation of the project.

DOCUMENT A

QUALITY ASSURANCE MANUAL MODIFICATIONS

QUALITY ASSURANCE MANUAL MODIFICATIONS

This document presents a compilation of the major modifications to the 1993 Quality Assurance Manual for the Installation of Lining Systems (QAM) compared to the June 15, 1990, Quality Assurance Manual for the Installation of Geosynthetic Lining Systems. This document is designed to allow a quick comparison between the two documents in order to determine possible impacts on existing projects and permits. However, we recommend that the user review this new QAM and compare it to the specific requirements of the existing project and permit.

Major general and specific modifications are presented below.

GENERAL MODIFICATIONS

1) New Sections - New sections have been added to address the soil components of lining systems. These sections include quality assurance procedures for soil liner material, granular drainage media, protective soil cover, vegetative soil cover and general earthfill. In addition, sections were added to address two relatively new products, geotextile/geonet composite and geosynthetic clay liner.

2) Eliminated Sections - The section regarding geogrids was eliminated for several reasons. First, variability of the different types of geogrids and the different applications made it very difficult to discuss without a particular product and application. Second, geogrids have not been widely used in land disposal applications. Finally, geogrids are typically not considered part of the lining system.

3) Removed Appendices - The appendices were eliminated as part of the QAM. The WMNA Specifications for Geosynthetics (Appendix A) were eliminated to allow the material specifications to be updated without having to modify the entire QAM. This also allows specifications to be developed per the site-specific requirements. The material specifications for geosynthetics have been updated and distributed as a separate guidance document.

   The Fingerprinting Protocol for HDPE Geosynthetics (Appendix B) was removed. This section was removed since it is felt that not enough information is known at this time to properly specify a fingerprint procedure for high density polyethylene. A fingerprinting protocol may be added in the future once more confidence exists in this area.

   Examples of Geosynthetic Quality Assurance Documentation (Appendix C) were removed to allow flexibility in the forms to be used.

4) Project Specification Reference - Reference to project specifications were added throughout the QAM. This allows the project specifications to be developed to address the site-specific conditions which cannot be addressed in the "generic" QAM. The QAM and the project specifications in conjunction with other project components make up the Quality Assurance Plan.

5) Project Manager Role - The Project Manager's role was modified to allow this role to serve more as the focal point for the project. The QAM provides the Project Manager more control for proper resolution of quality assurance issues.

6) New Section Format - The lining system component sections were modified to be independent sections. This will allow sections to be modified without requiring the entire QAM to be modified. This also allows only specific sections to be used as necessary.

7) Test Methods - The QAM references standardized test methods (ASTM and GRI) for required tests.

8) Owner - The term "Owner" replaced "WMNA" or "CWM" throughout the QAM. This minimizes any limitations on the use of the manual and is more consistent with the terms commonly used in project specifications.

SPECIFIC MODIFICATIONS

The attached tables present the specific modifications made to the QAM.

QUALITY ASSURANCE MANUAL MODIFICATIONS

New Section	Old Section	Modification Type	Description
1.1	1.1	Change	Scope section updated.
1.1	1.1	Change	QA now defined as "actions taken by Owner."
1.1	1.1	Deletion	Reference to EPA guidance.
1.2.1.2	1.2.1.2	Addition	Project Manager responsible for selection and approval of other parties.
1.2.2.4	1.2.2.4	Addition	Additional submittals may be required by Owner.
1.2.3.4	1.2.3.4	Deletion	Manufacturer required to provide a fingerprint for polyethylene products as part of pre-qualification submittal.
1.2.4	–	Addition	Earthwork Contractor section.
1.2.5.3	1.2.4.3	Change	Installing crew superintendent no longer required to have managed two projects and 1,000,000 SF previously.
1.2.5.3	1.2.4.3	Change	Master seamer no longer required to have 1,000,000 SF of experience.
1.2.6	–	Addition	Soil QA Consultant section.
1.2.7.1	1.2.5.1	Change	Geosynthetic QAC no longer required to be a firm independent from the Project Manager, Manufacturer, and Installer.
1.2.7.1	1.2.5.1	Change	Term "QA Managing Engineer" changed to "QA Certifying Engineer."
1.2.7.1	1.2.5.1	Addition	Geosynthetic QA Certifying Engineer shall visit the site often enough to be familiar with the details of the project.
1.2.7.1	1.2.5.1	Addition	"QA Certifying Engineer" may be known as "QA Officer."
1.2.7.2	1.2.5.2	Change	Term "Final Certification Report" changed to "Final QA Report."
1.2.7.2	1.2.5.2	Addition	Geosynthetic QAE assigns Geosynthetic Quality Assurance personnel to observe and document all installation activities requiring certification.
1.2.7.2	1.2.5.2	Addition	Geosynthetic QAE recommends the approval of the final liner acceptance to the Project Manager.
1.2.7.2	1.2.5.2	Addition	Geosynthetic QA Monitor documents measurements of uninstalled quantities.
1.2.7.2	1.2.5.2	Addition	Geosynthetic QAC shall properly and adequately assess differences.
1.2.7.3	1.2.5.3	Change	Only the QA Certifying Engineer is required to be a Professional Engineer.
1.2.7.3	1.2.5.3	Addition	Project Manager shall approve the Geosynthetic QAC.

QUALITY ASSURANCE MANUAL MODIFICATIONS			
New Section	Old Section	Modification Type	Description
1.2.7.3	1.2.5.3	Change	Geosynthetic QA Monitors no longer required for 1 of 4 (or one per project) to have minimum of 1,000,000 SF of field experience.
1.2.7.3	1.2.5.4	Change	Geosynthetic QAC required to provide corporate information (for pre-qualification) which includes proof of insurance and other coverages as required by statute and/or proposed contractual agreement.
1.2.7.4	1.2.5.4	Addition	Geosynthetic QAC required to provide examples of forms to be used in documentation of the project.
1.2.8	–	Addition	Soil QA Laboratory section.
1.2.9.1	1.2.6.1	Change	Geosynthetic QA lab no longer required to be independent from the Project Manager, Manufacturer, and Installer.
1.2.9.3	1.2.6.3	Addition	QA lab shall be 1) pre-qualified by Owner, 2) approved by Project Manager, 3) have properly maintained and periodically calibrated appropriate testing equipment, and 4) shall ensure that the laboratory testing is performed by personnel with experience and/or training in geosynthetic testing fundamentals.
1.3.1	–	Change	Lines of Communication Chart modified.
2.1.1	–	Addition	Soil Report section.
2.2.1	–	Addition	Soil Field Testing Report section.
2.2.2	2.2	Addition	Geosynthetic QAC required to include resolution of failed tests clearly documenting complete quality assurance documentation for destructive samples.
2.2.2	2.2	Addition	Destructive test reports shall contain resolution on failed test.
2.4.1	–	Addition	Soil Drawings section.
2.4.2	2.4	Addition	All surveying for as-built information shall be performed by a licensed land surveyor.
2.5	2.5	Change	Term "Final Certification Report" changed to "Final QA Report."
2.5	2.5	Change	Final QA Report general outline revised.
3.1	–	Addition	Soil Components Acceptance section.
9.1	–	Addition	Description and Applicability section.
9.2	4.1	Addition	Other appropriate representative may conduct annual manufacturing plant inspection.
9.3	4.2	Deletion	Manufacturer provide production date of the resin.
9.3	4.2	Addition	QC certificates must be dated.

QUALITY ASSURANCE MANUAL MODIFICATIONS

New Section	Old Section	Modification Type	Description
9.3	4.2	Deletion	Reclaimed polymer may not exceed 2% by weight.
9.3	4.2	Deletion	Manufacturer required to provide a characterization of the sheet based on results of fingerprinting test.
9.3	4.2	Addition	QC testing for puncture resistance and index friction (textured sheet only).
9.3	4.2	Deletion	QC testing of tear resistance.
9.3	4.2	Change	Frequency of Manufacturer QC testing is 50,000 SF instead of 40,000 SF.
9.3	4.2	Addition	QC testing includes stress cracking resistance.
9.3	4.2	Addition	Geosynthetic QAE must also verify that project specifications are provided to Installer by Project Manager.
9.4	4.3	Change	Conformance Testing section reorganized.
9.4.1	4.3.1	Change	Sample taken across entire width of roll judged by the Geosynthetic QAC not to be damaged.
9.4.2	4.3	Addition	Other conformance tests may be required by the project specifications.
9.4.3	4.3.2	Deletion	Retesting shall be at expense of Manufacturer.
9.5.1	4.4.1	Addition	Licensed land surveyor verify all lines and grades.
9.5.1	4.4.1	Addition	Professional Engineer has verified underlying soils.
9.5.1	4.4.1	Change	Underlying soils must meet criteria specified in project specifications.
9.5.2	4.4.2	Change	Anchor Trench section reformatted.
9.6.3	4.5.3	Addition	Project Manager will decide if installation is to be stopped or special procedures are to be used.
9.7.2.1	4.6.2.2	Change	Fusion Process and Extrusion Process sections were switched.
9.7.2	4.6.2	Change	No solvent or adhesive allowed.
9.7.4	4.6.4	Change	Remainder of successful trial seam sample retained by Project Manager.
9.7.5	4.6.5	Deletion	Movable protective layer note.
9.7.6.1	4.6.6.2	Change	For cold weather conditions (<32° F) seaming, new trial seams conducted when ambient drops more than 10° F instead of 5° F.
9.8.2	4.7.3	Change	Air pressure testing and vacuum testing sections switched.
9.8.2	4.7.3	Change	Installer now pressurizes double fusion to a pressure of approximately 30 psi.

QUALITY ASSURANCE MANUAL MODIFICATIONS			
New Section	Old Section	Modification Type	Description
9.8.2	4.7.3	Change	Pressure loss for air pressure testing no longer a 4 psi maximum, but as outlined in project specifications.
9.9.6	4.8.6	Change	Destructive test samples shall be shipped as soon as possible to expedite laboratory testing.
9.9.6	4.8.6	Change	Minimum acceptable test values provided in project specifications.
9.10.3	4.9.3	Change	Extrusion welding flap on inadequate fusion seams shall not exceed 100 feet instead of 50 feet.
9.10.4	4.9.4	Change	Defects and Repairs section reorganized.
9.11.1	4.10.1	Change	Any vehicles other than low ground pressure vehicles approved by Project Manager.
9.11.2	4.10.3	Addition	QAC shall verify that a representative of the Geosynthetic QAC shall be present at all times when the installer is welding geomembrane to appurtenant structures.
10.1	–	Addition	Definition and Applicability section.
10.3	5.2	Change	Written certification of "minimum values" instead of "minimum average roll values."
10.3	5.2	Addition	QC certificates must be dated.
10.3	5.2	Deletion	QC testing for thickness.
10.4.1	5.3.1	Change	Samples taken from any portion of the roll not damaged.
10.4.2	5.3	Deletion	Conformance testing for thickness of geotextiles.
10.4.3	5.3.2	Deletion	Retesting shall be at expense of Manufacturer.
10.6	5.5	Addition	Adjacent seam shall be staggered horizontally.
10.7	5.6	Change	Defects and Repairs section reorganized.
10.7.3	5.6	Change	Geotextile patches on sideslopes may be thermally bonded in accordance with project specifications.
10.7.3	5.6	Addition	Final decision as to appropriate repair shall be agreed upon.
11.1	–	Addition	Definition and Applicability section.
11.3	6.4	Addition	QC certificates must be dated.
11.3	6.2	Deletion	Reclaimed polymer may not exceed 2% by weight.
11.4.1	6.3.1	Change	Samples taken from any portion of the roll not damaged.
11.4.3	6.3.2	Deletion	Retesting shall be done at the expense of Manufacturer.
11.5	6.4	Addition	Rolls shall be delivered wrapped in plastic.

QUALITY ASSURANCE MANUAL MODIFICATIONS			
New Section	Old Section	Modification Type	Description
11.7	6.6	Change	Defects and Repairs section reorganized.

GEOSYNTHETIC MATERIAL SPECIFICATIONS

GEOSYNTHETIC MATERIAL SPECIFICATIONS

TABLE 1 - HDPE SMOOTH GEOMEMBRANE

Property	Qualifier	Unit	Specified Value	All Thicknesses	Test Method
Thickness	min. average	mils	40 60 80 100		ASTM D751*
Thickness	min. reading	mils	36 54 72 90		ASTM D751*
Density (geomembrane)	min.	g/cc	0.940		ASTM D1505
Melt Index (resin)	max.	1g/10 min.	1.0		ASTM D1238
Tensile Properties: (each direction)					
1. Yield strength	min.	lb/in	88 132 176 220	2200 psi	ASTM D638*
2. Break strength	min.	lb/in	152 228 304 380	3800 psi	ASTM D638*
3. Elongation at yield	min.	%	12		ASTM D638*
4. Elongation at break	min.	%	750		ASTM D638*
Tear Strength	min.	lb	28 42 56 70	700 lb/in	ASTM D1004
Puncture Resistance	min.	lb	72 108 144 180	1800 lb/in	ASTM D4833
Low Temperature	max.	deg. C	-60		ASTM D746
Carbon Black Content	range	%	2.0 to 3.0		ASTM D1603
Carbon Black Dispersion	rating	N/A	A-1, A-2, or B-1		ASTM D3015 NSF Modified
Dimensional Stability (each direction)	max. change	%	2.0		ASTM D1204*
Environmental Stress Crack	min.	hours	200		GRI GM-5b
Multi-Axial Elongation	min.	%	20		GRI GM-4

Note:
*Test Methods Modified per Table 6.

GEOSYNTHETIC MATERIAL SPECIFICATIONS

TABLE 2 - HDPE TEXTURED GEOMEMBRANE

Property	Qualifier	Unit	Specified Value	All Thicknesses	Test Method
Thickness (base sheet)	min. average	mils	40 60 80 100		ASTM D751*
Thickness (base sheet)	min. reading	mils	36 54 72 90		ASTM D751*
Density (geomembrane)	min.	g/cc	0.940		ASTM D1505
Melt Index (resin)	max.	1g/10 min.	1.0		ASTM D1238
Tensile Properties: (each direction)					
1. Yield strength	min.	lb/in	88 132 176 220	2200 psi	ASTM D638*
2. Break strength	min.	lb/in	88 132 176 220	2200 psi	ASTM D638*
3. Elongation at yield	min.	%	12		ASTM D638*
4. Elongation at break	min.	%	200		ASTM D638*
Tear Strength	min.	lb	28 42 56 70	700 lb/in	ASTM D1004
Puncture Resistance	min.	lb	72 108 144 180	1800 lb/in	ASTM D4833
Low Temperature	max.	deg. C	-60		ASTM D746
Carbon Black Content	range	%	2.0 to 3.0		ASTM D1603
Carbon Black Dispersion	rating	N/A	A-1, A-2, or B-1		ASTM D3015 NSF Modified
Dimensional Stability (each direction)	max. change	%	2.0		ASTM D1204*
Environmental Stress Crack	min.	hours	200		GRI GM-5b
Multi-Axial Elongation	min.	%	15		GRI GM-4
Index Friction	min. avg.	degree	40		GRI GS-7

Note:
*Test Methods Modified per Table 6.

GEOSYNTHETIC MATERIAL SPECIFICATIONS

TABLE 3 - HDPE GEOMEMBRANE SEAMS

Property	Qualifier	Unit	Specified Value				All Thicknesses	Test Method
Thickness	min. average	mils	40	60	80	100		
Bonded Seam Strength	min.	lb/in	88	132	176	220	2200 psi	ASTM D4437*
Peel Adhesion:								
Fusion	min.	lb/in	60	90	120	150	1500 psi	ASTM D4437*
Extrusion	min.	lb/in	52	78	104	130	1300 psi	ASTM D4437*

Note:
*Test Methods Modified per Table 6.

GEOSYNTHETIC MATERIAL SPECIFICATIONS				
TABLE 4 - HDPE SOLID GEONET				
Property	**Qualifier**	**Unit**	**Value**	**Test Method**
Thickness	min.	mils	200	ASTM D751
Mass per Unit Area	min.	lb/ft^2	0.16	ASTM D3776 (Option C)
Polyethylene Content	min.	%	95	—
Density (black resin)	min.	g/cc	0.940	ASTM D1505
Carbon Black Content	range	%	2.0 to 3.0	ASTM D1603
Melt Index	max.	g/10 min.	1.0	ASTM D1238 (Condition 190/216)
Tensile Strength (machine direction)	min.	lb/in	40	ASTM D1682*
Transmissivity	min.	m^2/sec	1×10^{-3}	ASTM D4716*

Note:
*Test Methods Modified per Table 6.

GEOSYNTHETIC MATERIAL SPECIFICATIONS				
TABLE 5 - HDPE FOAMED GEONET				
Property	**Qualifier**	**Unit**	**Value**	**Test Method**
Thickness	min.	mils	200	ASTM D751
Mass per Unit Area	min.	lb/ft^2	0.13	ASTM D3776 (Option C)
Polyethylene Content	min.	%	95	--
Density (black resin)	min.	g/cc	0.940	ASTM D1505
Carbon Black Content	range	%	2.0 to 3.0	ASTM D1603
Melt Index	max.	g/10 min.	1.0	ASTM D1238 (Condition 190/216)
Tensile Strength (machine direction)	min.	lb/in	23	ASTM D1682*
Transmissivity	min.	m^2/sec	1×10^{-3}	ASTM D4716*

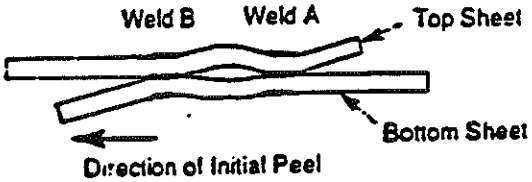
Note:
*Test Methods Modified per Table 6.

GEOSYNTHETIC MATERIAL SPECIFICATIONS		
TABLE 6 - TEST METHOD MODIFICATIONS		
Property	**Test Method**	**Modifications**
Thickness	ASTM D751	Measure thickness at one foot intervals across the width of the roll (perpendicular to the machine direction) and report average, standard deviation, and lowest individual readings.
Tensile Properties	ASTM D638	Type IV Die. ASTM D638 test specimen shall be used. The grip separation shall be 2.5 inches. This test does not require the use of extensometers. The rate of grip separation will be 2 inches per minute. A gauge length of 1.3 inches for yield values, and 2.0 inches for break values shall be used to calculate elongation from grip movement.
Dimensional Stability	ASTM D1204	100° C for 1 hour.
Tensile Strength	ASTM D1682	Test method modified as follows: 1) Use 4 in x 8 in specimens. 2) Use grip separation of 4 in. 3) Use test rate of 8 in/min. 4) Continue test until first strand separates completely. 5) Report averages of 5 tests in machine direction.
Bonded Seam Strength and Peel Adhesion	ASTM D4437	For shear tests, the sheet shall yield before failure of the seam. For peel adhesion, seam separation shall not extend more than 10% into the seam. For either test, testing shall be discontinued when the sample has visually yielded. Sample failure shall conform to a passing configuration as outlined in Figure A-1.
Transmissivity	ASTM D4716	Gradient = 1.0; Confining Pressure = 15,000 psf (solid geonet), 4,000 psf (foamed geonet) measured between two steel plates one hour after application of confining pressure.

FIGURE A-1

000402

Schematic of Untested Specimen



Types of Break	Locus-of-Break Code	Break Description	Classification[a]
	AD	Adhesion failure.	Non-FTB
	BRK	Break in sheeting. Break can be in either top or bottom sheet.	FTB
	SE1	Break at outer edge of seam. Break can be in either top or bottom sheet.	FTB
	SE2	Break at inner edge of seam through both sheets.	FTB
	AD-BRK	Break in first seam after some adhesion failure. Break can be in either the top or bottom sheet.	FTB

[a] FTB = Film - Tear Bond

NOT TO SCALE

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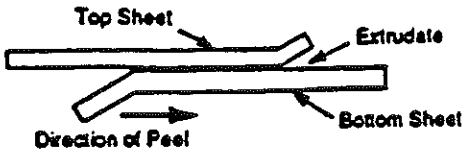
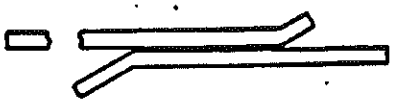
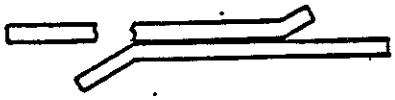
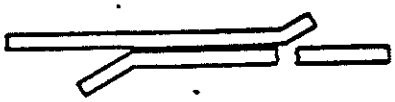
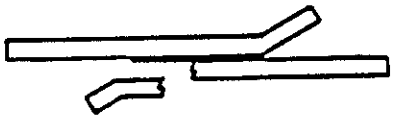
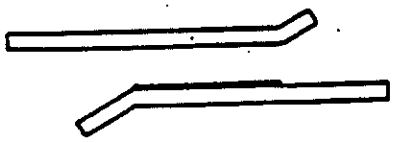
FIGURE A-1 (cont.)

000493

Schematic of Untested Specimen



Location of Break	Locus-of-Break Code	Break Description	Classification[a]
	BRK	Break in sheeting outside weld area. Break can be in either the top or bottom sheet	FTB
	SE1	Break in top sheet at seam edge.	FTB
	SE2	Break in bottom sheeting at seam edge	FTB
	SE3	Break in bottom sheeting at seam edge. (Applicable to peel only).	FTB
	AD-BRK	Break in sheeting after some adhesion failure between extrudate and surface of the sheeting. Break can be in either the top or bottom sheet.	FTB
	AD	Failure in adhesion between the extrudate and the sheeting surface.	Non-FTB

[a] FTB = Film - Tear Bond

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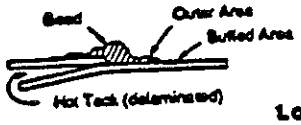
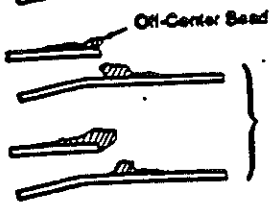
FIGURE A-1 (cont.)

Schematic of Untested Specimen



Types of Breaks	Locus-of-Break Code	Break Description	Classification[a]
	AD1	Failure in adhesion. Specimens may also delaminate under the bead and break through the thin extruded material in the outer area.	Non-FTB
	AD2	Failure in adhesion.	Non-FTB
	AD-WLD	Break through the fillet. Breaks through the fillet range from breaks starting at the edge of the top sheet to breaks through the fillet after some adhesion failure between the fillet and the bottom sheet.	Non-FTB[b]
	SE1	Break at seam edge in the bottom sheet. Specimens may break anywhere from the bead/outer area edge to the outer area/buffed area edge. (Applicable to shear only).	FTB
	SE2	Break at seam edge in the top sheet. Specimens may break anywhere from bead/outer area edge to the outer area/buffed area edge.	FTB
	SE3	Break at seam edge in the bottom sheet. (Applicable to peel only).	FTB
	BRK1	Break in the bottom sheeting. A "B" in parentheses following the code means the specimen broke in the buffed area. (Applicable to shear only).	FTB
	BRK2	Break in the top sheeting. A "B" in parentheses following the code means the specimen broke in the buffed area.	FTB
	AD-BRK	Break in the bottom sheeting after some adhesion failure between the fillet and the bottom sheet. (Applicable to peel only).	FTB
	HT	Break at the edge of the hot tack for specimens which could not be delaminated in the hot tack.	No Test

[a] FTB = Film - Tear Bond.

[b] Acceptance of AD-WLD breaks may depend on whether test values meet a minimum specification value and not on classification as a FTB or non-FTB break.

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Lining of Waste Containment and Other Surface Impoundment Facilities

DOCUMENT C

SOIL LINER ACCEPTABLE ZONE PROCEDURE

SOIL LINER ACCEPTABLE ZONE PROCEDURE

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SOIL LINER ACCEPTABLE ZONE PROCEDURE

1.0 INTRODUCTION

One of the most significant factors affecting the performance of compacted soil liners is the adequate control of water content and dry unit weight during construction. A carefully written compaction specification can improve the likelihood of achieving the required hydraulic conductivity while also satisfying other factors affecting performance such as strength, compressibility and desiccation resistance. Because a soil liner is meant to be a hydraulic barrier, hydraulic conductivity requirements should be the primary factor affecting the design of a compaction specification. The specification should then be tightened as necessary to meet other performance standards.

2.0 CONCEPT OF ACCEPTABLE ZONE

Figure 1 shows an example of three compaction curves (Figure 1a) and three hydraulic conductivity curves (Figure 1b) that correspond to high compactive effort (modified Proctor), moderate compactive effort (standard Proctor), and low compactive effort (reduced Proctor) for a particular soil. It is believed that these compactive efforts simulate the range of compactive efforts that can be achieved in the field (Benson and Daniel, 1990). A description of the procedure used to achieve reduced Proctor compactive effort is included later in this document.

For each compaction curve shown in Figure 1, the lowest hydraulic conductivity is achieved for water contents slightly in excess of optimum water content. Furthermore, similar water contents can yield radically different hydraulic conductivities if the compactive effort is changed. For example, at a water content of 11%, the hydraulic conductivity of this soil can be as low as 2×10^{-9} cm/sec and as high as 1×10^{-6} cm/sec. Hence, to ensure that required hydraulic conductivities are achieved, a compaction specification should be designed that delineates a zone in the compaction plane which yields the desired hydraulic conductivity for the range of compactive efforts that may be realized in the field. This zone of water contents and dry unit weights is called an "Acceptable Zone". For most cases, where a low hydraulic conductivity is desired, the Acceptable Zone will have a shape similar to the shaded region shown in Figure 1c.

3.0 DEVELOPING AN ACCEPTABLE ZONE

The procedure to develop an Acceptable Zone involves: (1) establishing a zone of water content and dry unit weight that yields the required hydraulic conductivity, and (2) modifying the zone to account for other factors beside hydraulic conductivity. The recommended approach is:

1. Compact soil in the laboratory with modified Proctor (ASTM D1557), standard Proctor (ASTM D698) and reduced Proctor procedures. Protocol for reduced Proctor compaction is the same as the protocol used for standard Proctor compaction, except 15 blows per layer are applied (Daniel and Benson, 1990). Six specimens should be compacted at each compactive effort and compaction curves should be graphed based on the results (Figure 2a).

Ideally, processing of the soil prior to the compaction test (i.e., clod size reduction and moisture conditioning) should simulate conditions expected in the field if possible (Benson and Daniel, 1990). Nevertheless, whatever procedure is employed, the method used to process the soil prior to the compaction test should be documented carefully. Crushing the soil to pass the 3/4 inch sieve prior to the compaction test and using hydration times that will be used during construction is recommended. This procedure is likely to simulate the sensitivity of hydraulic conductivity to water content that is expected in the field. Details regarding this procedure can be found in Benson and Daniel (1990).

2. The compacted specimens should be permeated using standard procedures (e.g., ASTM D5084). Care should be taken to ensure the permeation procedures are correct, with important details such as degree of saturation and confining pressure carefully selected. Guidance on these details can be found in Daniel et.al. (1984) and Carpenter and Stephenson (1986). The permeation procedures should be carefully documented. Hydraulic conductivities obtained from the tests should then be plotted as a function of molding water content and a line (or lines) should be drawn that delineates the desired hydraulic conductivity (Figure 2b).

3. Replot the compaction curves using different symbols for those specimens yielding acceptable hydraulic conductivities (Figure 2c). A simple method is to use open symbols for specimens with hydraulic conductivities that are unacceptable and solid symbols for acceptable hydraulic conductivities. An "Acceptable Zone" should then be drawn (Figure 2c) that encompasses the data points with acceptable hydraulic conductivities. Some judgment may be necessary in constructing the Acceptable Zone.

4. Modify the Acceptable Zone based on other considerations (Figure 2d). For example, if shear strength is a concern, a limit on water content and dry unit weight should be specified to ensure that excessively weak soils are not present. Other factors that may be considered when modifying the Acceptable Zone are: geomembrane interface friction (Seed and Boulanger, 1991), desiccation (Wu and Daniel, 1993), freeze-thaw (Chamberlin and Ayorinde, 1991), cracking by settlement distortions, and constructability. Modifications should only be made that reduce the size of the Acceptable Zone.

   In many cases, the dry side of the Acceptable Zone can be defined by the line of optimums. Only in special cases, such as construction in arid regions where desiccation is a concern, should water contents dry of the line of optimums be included in the Acceptable Zone.

4.0 VARIABLE SOIL PROPERTIES

In some cases, the borrow source may be so variable that different Acceptable Zones are needed to describe soils that have significantly different properties. If the soils can be easily distinguished in the borrow pit and/or the construction area, separate Acceptable Zones can be developed and supplied to field inspectors. If the soils are not easily distinguished, a composite

Acceptable Zone can be developed by overlaying the Acceptable Zones (Figure 3). The intersection of the Acceptable Zones is then the composite Acceptable Zone.

5.0 USE OF THE ACCEPTABLE ZONE

The Acceptable Zone can be used directly in the field. Inspectors measuring water content and dry unit weight can plot the field data on the compaction curve. If the data falls in the Acceptable Zone and no visible defects are present, the compaction is deemed acceptable. Otherwise, the soil needs additional processing and compaction.

REFERENCES

Benson, C.H., and D. E. Daniel (1990), "Influence of Clods on the Hydraulic Conductivity of Compacted Clay", Journal of Geotechnical Engineering, American Society of Civil Engineers, New York, Vol. 116, No. 8, pp. 1231-1248.

Daniel, D.E., and C.H. Benson (1990), "Water Content-Density Criteria for Compacted Soil Liners", Journal of Geotechnical Engineering, American Society of Civil Engineers, New York, Vol. 116, No. 12, pp. 1811-1830.

Daniel, D.E., et al. (1984), "Permeability Testing with Flexible-Wall Permeameters", Geotechnical Testing Journal, Vol. 7, No. 3, pp. 113-122.

Carpenter, G. and R. Stephenson (1986), "Permeability Testing in the Triaxial Cell", Geotechnical Testing Journal, Vol. 9, No. 1, pp. 3-9.

Seed, R. and R. Boulanger (1991), "Smooth HDPE-Clay Liner Interface Shear Strengths: Compaction Effects", Journal of Geotechnical Engineering, American Society of Civil Engineers, New York, Vol. 117, No. 4, pp. 686-693.

Wu, Y.K. and D.E., Daniel (1993), "Compacted Clay Liners and Covers for Arid Sites", submitted to Journal of Geotechnical Engineering, American Society of Civil Engineers, New York, Vol. 119, No. 2, pp. 223-257.

Chamberlin, E. and O. Ayorinde (1991), "Freeze-Thaw Effects on Clay Covers and Liners, Proceedings of the 6th Int'l Specialty Conference on Cold Regions Engineering, American Society of Civil Engineers, pp. 136-151.

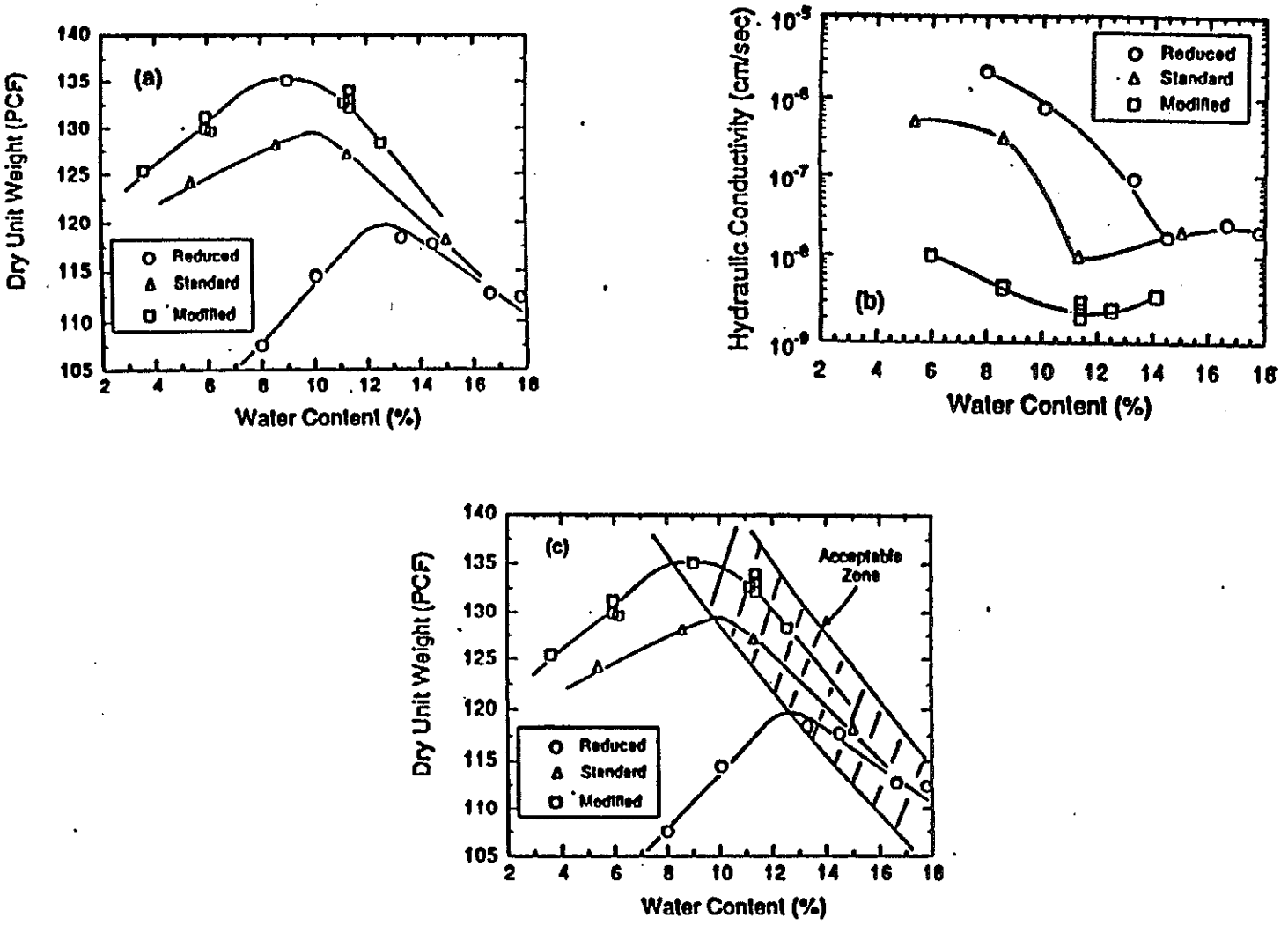

Figure 1. Compaction Curves (a) and Hydraulic Conductivity Curves (b) for Three Compactive Efforts and an Acceptable Zone to Yield Low Hydraulic Conductivity (c).

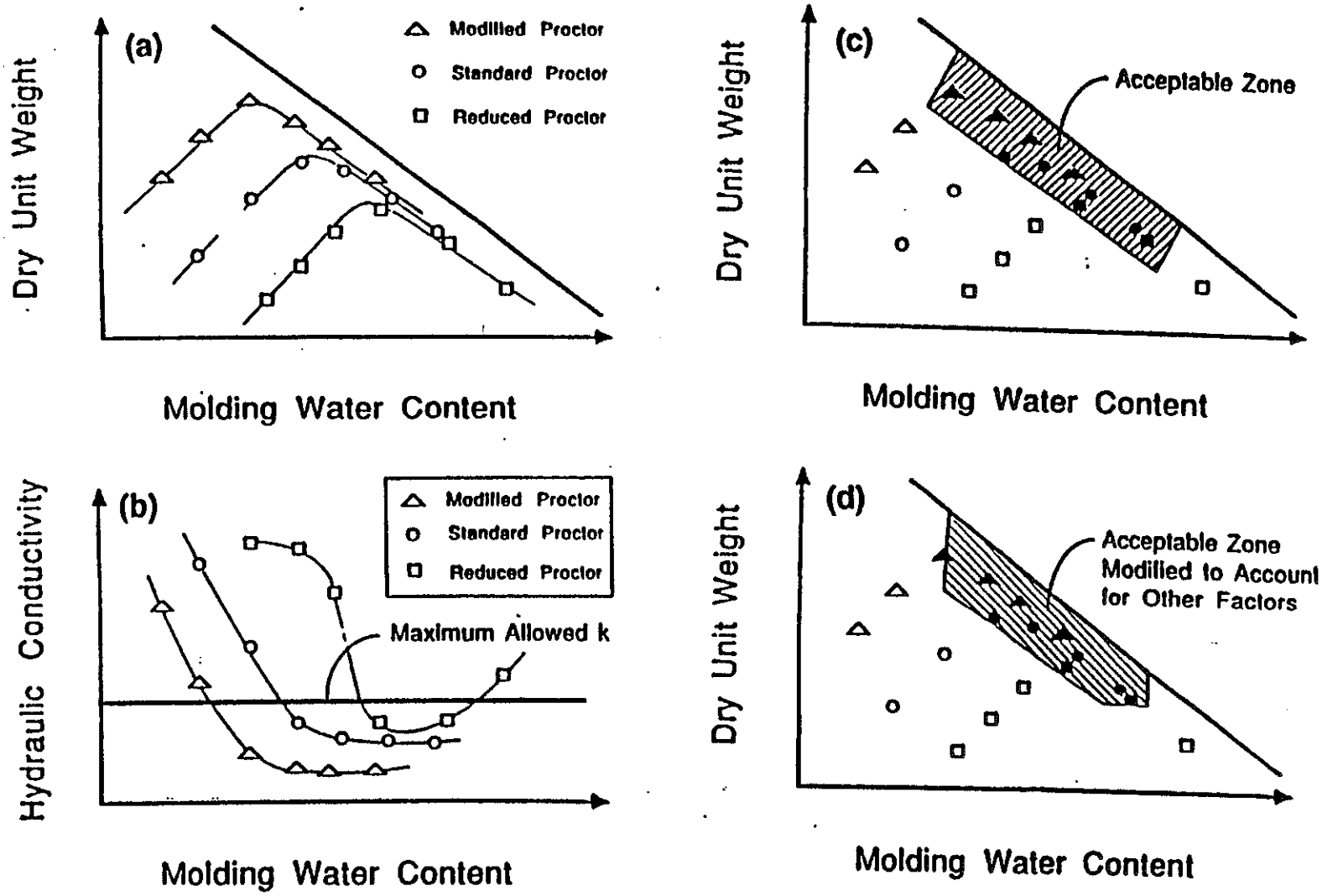

Figure 2. Recommended Design Procedure. (a) Determine Compaction Curves with Modified, Standard, and Reduced Proctor Compactive Effort; (b) Determine Hydraulic Conductivity of Compacted Specimens; (c) Replot Compaction Curves Using Solid Symbols for Compacted Specimens with Acceptable Hydraulic Conductivities; and (d) Modify Acceptable Zone Based on Other Design Factors.

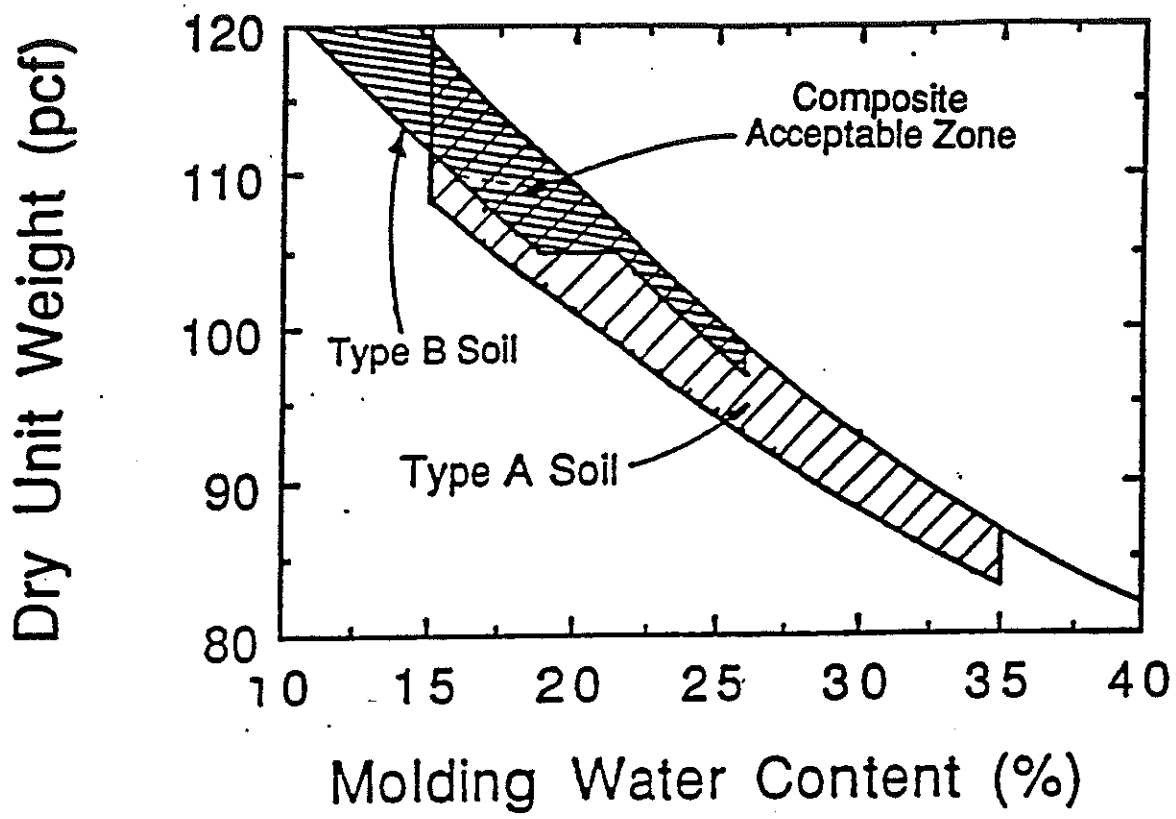

Figure 3. Developing a Composite Acceptable Zone for Construction with Variable Soil Types.

DOCUMENT D

SOIL LINER TEST PAD PROGRAM

SOIL LINER TEST PAD PROGRAM

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FIGURES

SOIL LINER TEST PAD PROGRAM

000506

1.0 INTRODUCTION

The purpose of a test pad is to verify that the materials and installation requirements specified in the project plans and specifications to be used during construction of soil liners can meet the required performance standard. This test pad program will also allow the Earthwork Contractor, Designer, Soil Quality Assurance Consultant (Soil QAC) and the Project Manager to identify appropriate placement and compaction procedures. Once the detailed construction procedures have been established during the test pad program, the Earthwork Contractor and the Soil QAC will monitor the soil liner construction procedures as an indicator that the performance standards are being achieved. This test pad program may be modified based on site-specific design, construction and regulatory considerations.

2.0 CONSTRUCTION PREPARATION

2.1 Test Pad Material

Source evaluation testing of the proposed soil liner material shall be performed prior to construction of the test pad. The material shall be evaluated in accordance with Section 4.1 of this document. These tests shall provide the basic relationship of hydraulic conductivity with varying water content, dry unit weight and compactive effort (Figure 1).

2.2 Construction Equipment

The equipment to be used for a test pad shall be proposed by the Earthwork Contractor and approved by the Soil QAC and Project Manager. The equipment to be used for the test pad shall be consistent with the equipment which will be used during liner construction.

2.3 Subgrade Preparation

The area within the limits of the test pad shall be cleared and grubbed of all trees, brushes, stumps, roots, debris, trash, and any other vegetation or objectionable material. Following clearing and grubbing, the area shall be stripped of topsoil. Topsoil shall be stockpiled in an area designated by the Project Manager.

The surface of the subgrade shall be proof-rolled so as to be free of soft zones, irregularities, loose earth, and abrupt changes in grade. The subgrade and test pad shall be sloped at an approximate 2 percent grade. Line and grades shall be controlled by survey. No standing water or excessive moisture shall be allowed on the surface of the subgrade. The surface shall be observed by the Soil QAC prior to beginning construction of the test pad.

3.0 TEST PAD CONSTRUCTION

The test pad shall be a rectangle approximately 100 feet long by 50 feet wide (Figure 2). The test pad shall be constructed in uniform horizontal lifts with a total thickness consistent with the project plans and specifications. The construction procedures, which vary with the lift considered, are intended to allow determination of a relationship between soil measurements and compaction method parameters. Soil measurements include water content, dry unit weight, and hydraulic conductivity. Compaction method parameters includes compactor characteristics, thickness of compacted/uncompacted layers, number of compactor passes, and water content.

3.1 First Lift

1. A geotextile or drainage layer shall be placed by the Earthwork Contractor over the subgrade area of the test pad. The geotextile or a drainage layer should extend beyond the edge of the test pad allowing an outlet for test pad infiltration.

2. The first lift of test pad material shall be placed to a thickness resulting in 6 inches after compaction or as required in the project specifications.

3. Soil water content shall be maintained in the Acceptable Zone as determined during source evaluation testing. The Earthwork Contractor shall adjust the water content as necessary to obtain the specified density criteria.

4. The test pad material shall be compacted with two one-way coverages using the previously agreed upon compaction equipment.

5. The Earthwork Contractor shall allow the Soil QAC to perform in-place measurements of moisture content and density tests and collect soil samples.

6. Holes left in the lift shall be repaired in accordance with methods outlined in the appropriate QAM and project specifications.

7. The test pad material shall be compacted a second time by applying two more one-way coverages with the selected compactor.

8. A second series of tests shall be taken near the original tests. Repeat steps 5 and 6.

9. The test pad material shall be compacted a third time by applying two more, one-way coverages.

10. A third series of tests shall be taken near the first and second tests. Repeat steps 5 and 6.

11. Steps 9 and 10 shall be repeated and continued until specified compaction criteria are obtained as identified by the Soil QAC.

3.2 Second Lift

1. The loose thickness of the second lift shall be such that the thickness of the compacted lift will be 6 inches after compaction or as required by the project specifications.

2. A competent bond with the first lift shall be achieved by the Earthwork Contractor and observed by the Soil QAC.

3. Steps 3 through 11 of Section 3.1 shall be repeated.

3.3 Remaining Lifts

1. The loose thickness of the remaining lifts shall be such that the thickness of the lifts will be 6 inches after compaction or as required by the project specifications.

2. The procedures for compacting and testing the remaining lifts shall be those that have been tested and proven effective during the compaction of the second lift.

3.4 Final Surface Preparation

The final surface grade of the test pad shall be rolled with a smooth steel drum or pneumatic roller so as to be free of irregularities, loose earth, and abrupt changes in grade. All stones larger than 1 inch shall be removed. Stones which are smaller than 1 inch and are judged by the Soil QAC to be detrimental to a geomembrane liner shall also be removed by the Earthwork Contractor. Clear or white temporary plastic sheets shall be placed over the test pad immediately after the completion of the final surface preparation. Observations and documentation of desiccation cracking versus time shall be made on the uncovered section of the test pad.

4.0 TESTING AND OBSERVATIONS

4.1 Construction Preparation

The Soil QAC shall perform testing on the soil liner material prior to its use in the test pad. Source evaluation testing will include at a minimum the following unless otherwise specified in the project specifications:

- Water Content (ASTM D2216)
- Particle Size (ASTM D422, D1140)
- Atterberg Limits (ASTM D4318)
- Laboratory Compaction (ASTM D698 for standard Proctor or ASTM D1557 for modified Proctor)
- Laboratory Hydraulic Conductivity at a specified compaction (ASTM D5084)
- Soil Classification (ASTM D2487)

The Soil QAC shall observe the prepared subgrade for firmness, smoothness, and absence of abrupt changes in grade. The subgrade shall be surveyed to serve as the origin for determining thicknesses.

4.2 Test Pad Construction

The Soil QAC shall perform tests and make observations during the construction of the test pad to enable development of a curve providing in-place dry unit weight versus number of compactor coverages (Figure 3). Test sample locations shall be selected by the Soil QAC. An example of test sample locations and configuration is provided in Figure 4.

During the construction of the first and second lifts, the Soil QAC shall perform the following activities:

- Estimate the thickness of the loose lifts
- Count the number of compactor coverages and observe compactor coverage of the test pad
- Perform a minimum of eight nuclear gauge in-place measurements of water content and dry unit weight (ASTM D2922) for every two compactor coverages, and a minimum of one in-place test using the sand-cone method (ASTM D1556) to verify the nuclear gauge readings; compute degree of compaction (in-place dry unit weight divided by the Standard Proctor maximum dry unit weight); collect four additional soil samples for moisture content determination (ASTM D2216)
- Observe the repair of holes left in the lift as a result of testing and soil sample collection

During construction of the remaining lifts, the Soil QAC shall perform the following activities:

- Verify that the thickness of the loose lift does not exceed the maximum loose lift thickness determined from testing of the second lift
- Count the number of compactor coverages, determined from testing of the second lift, which are necessary to achieve the compaction in the Acceptable Zone and observe compactor coverage of the test pad
- Perform a minimum of eight tests nuclear gauge in-place measurements (ASTM D2922) and one sand-cone test (ASTM D1556) per lift to verify the adequacy of the construction procedures previously established

During the construction of the test pad, the Soil QAC shall collect a minimum of six undisturbed Shelby tube samples or carve two 14" long, 14" wide, 8" thick undisturbed block soil samples (large-scale samples) from varying depths of the completed test pad. The samples shall be waxed or otherwise protected to retain natural water. The large-scale block samples should be trimmed to a 12" diameter and 6" thick sample in the laboratory. The samples should be tested in the laboratory for the following:

- Water Content (ASTM D 2216)
- Particle Size (ASTM D422)
- Atterberg Limits (ASTM D4318)
- Laboratory Hydraulic Conductivity (ASTM D5084)
- Soil Classification (ASTM D2487)

The laboratory hydraulic conductivity tests performed on the large-scale samples may be used in substitution of the field hydraulic conductivity tests on the test pad. Large-scale samples allow field-scale conditions to be simulated.

The Soil QAC shall observe the test pad to verify the adequacy of the bonding between adjacent lifts. Such observation shall be exercised on the portion of the test pad which has been excavated to permit removal of undisturbed soil block samples and/or the sand-cone density testing.

4.3 Final Surface Preparation

The Soil QAC shall observe the prepared surface for firmness, smoothness, and absence of abrupt changes in grade. The final surface will be surveyed to verify the test pad thickness.

5.0 DOCUMENTATION

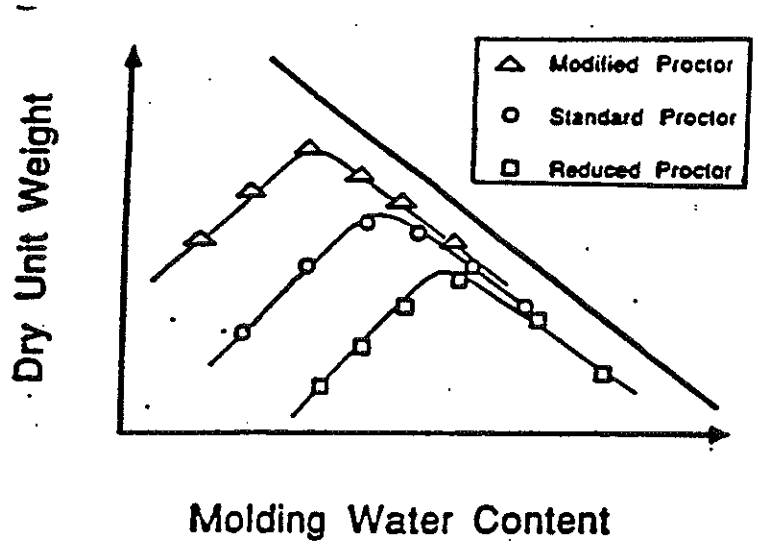
The Soil QAC shall document activities associated with the preparation, construction, testing, and observation of the test pad and provide recommendations on placements and compaction procedures. A documentation summary report shall be prepared that contains information on the test pad material, construction equipment, subgrade preparation, test pad construction, and testing and observations. The report shall also include daily reports of construction activities and oral communications with the Earthwork Contractor and Project Manager.

The Soil QAC shall provide a water content/dry unit weight relationship for the test pad material and other source material test results. The Soil QAC shall document testing and observations on subgrade preparation, test pad construction, and final surface preparation, including but not limited to:

- compactor type, configuration, and weight for sheepsfoot compactors, drum diameter and length, empty and ballasted weight, length and face area of feet, and yoking arrangement
- thicknesses of lifts prior to and after compaction

- dry unit weight versus number of compactor coverages for each lift thickness, as specified in Section 4.2
- number of compactor coverages which will provide the specified compaction in the Acceptable Zone and hydraulic conductivity that meets the performance standard
- procedure to bond lifts
- recommended installation procedures
- results of water content, in-place density and degree of compaction
- description of repair of holes left in the lift as a result of density testing and soil sample collection, as specified in Section 4.2
- results of laboratory hydraulic conductivity testing and other soil property tests performed on undisturbed soil samples
- drawings of the test pad and locations of all test samples for each lift
- cross sections of the test pad showing number of lifts and lift thickness
- description of actual construction procedures
- test pad excavation for removal of undisturbed soil samples and observations of layer bonding.

The Soil QAC shall submit the final documentation summary report to the Project Manager.



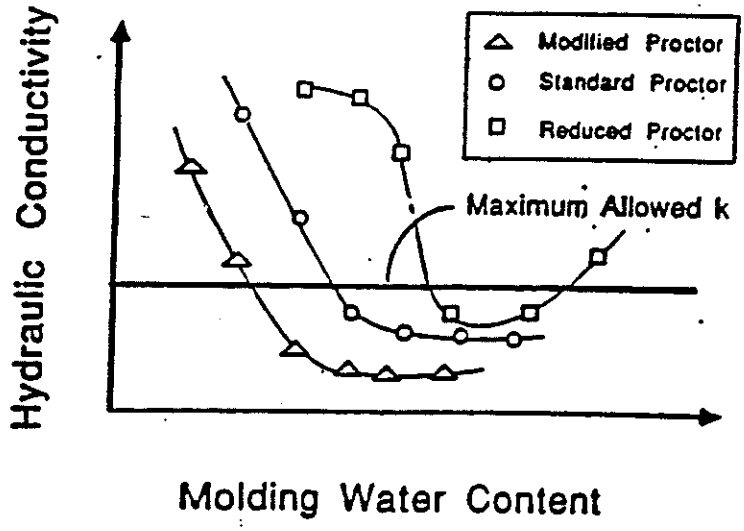
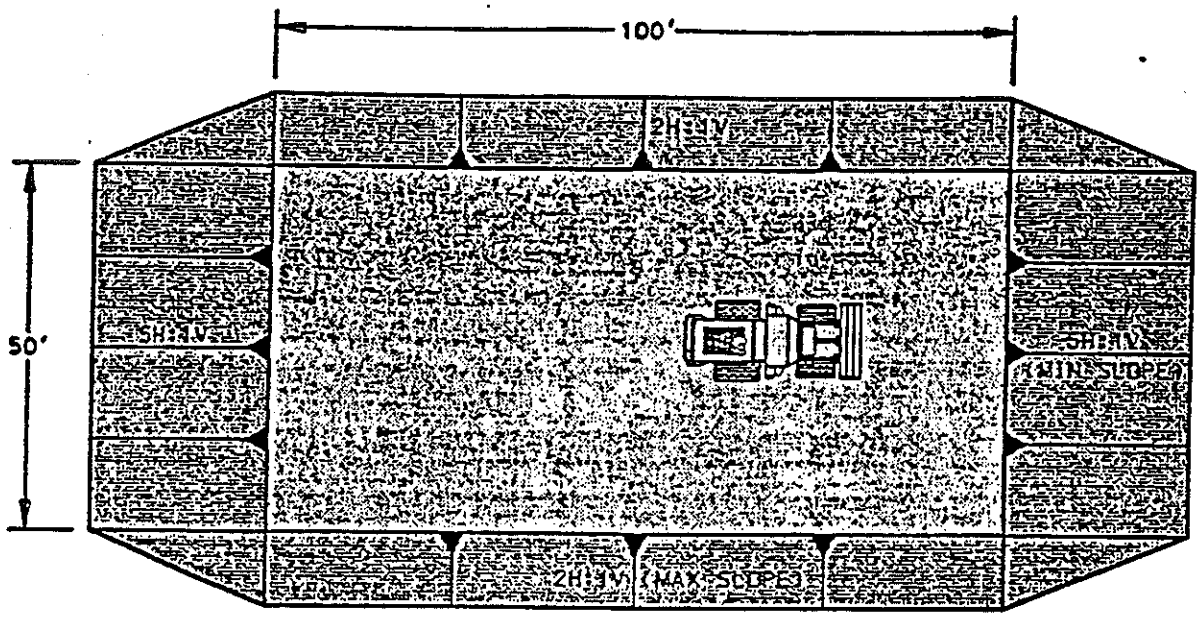


FIGURE 1 – COMPACTION CURVES AND HYDRAULIC CONDUCTIVITY CURVES



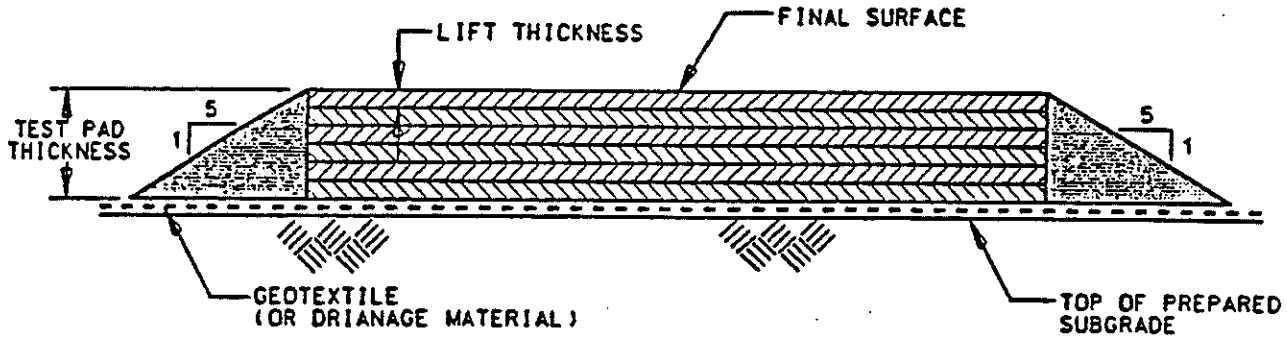


FIGURE 2 – TYPICAL TEST PAD CONFIGURATION

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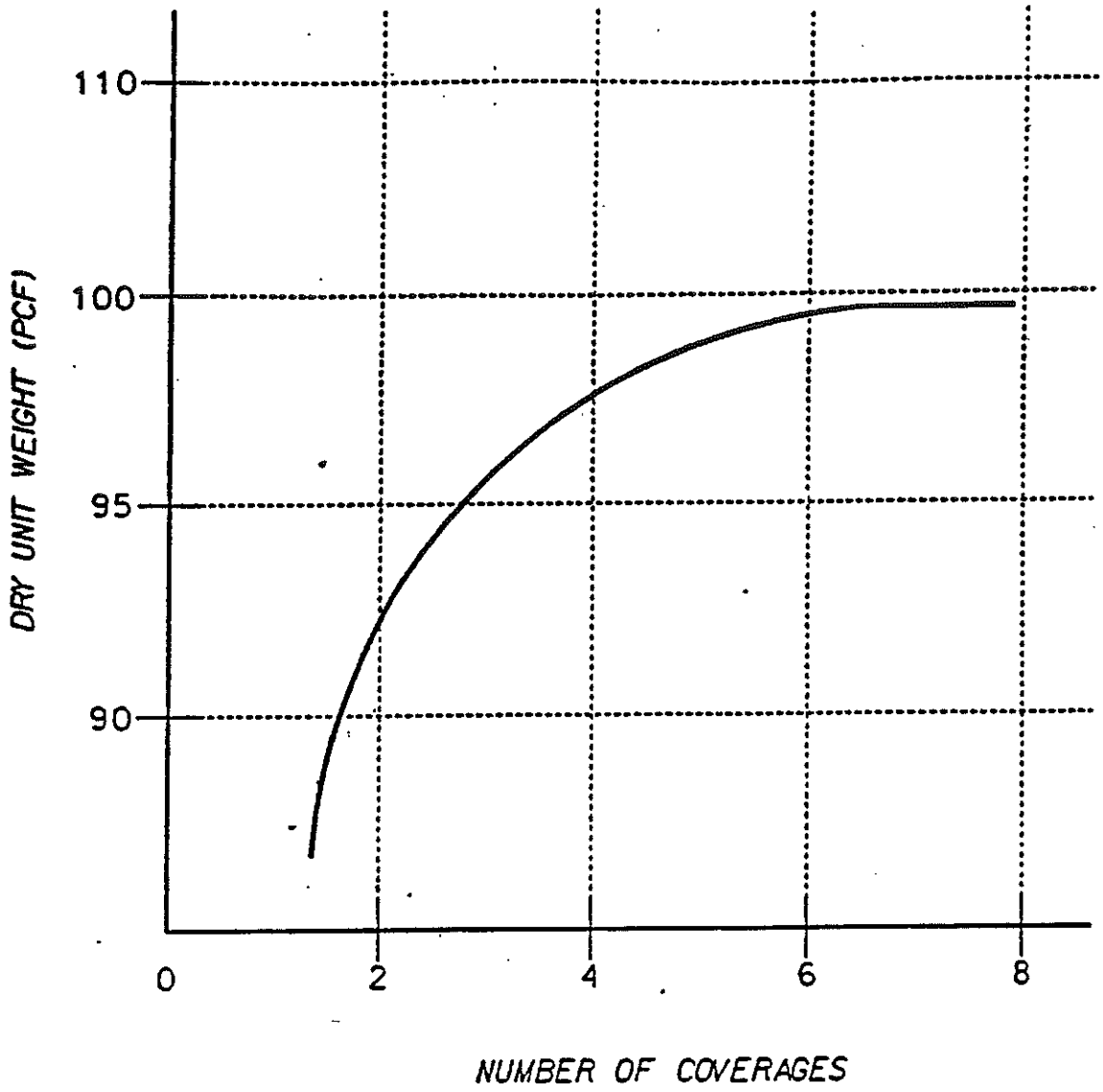
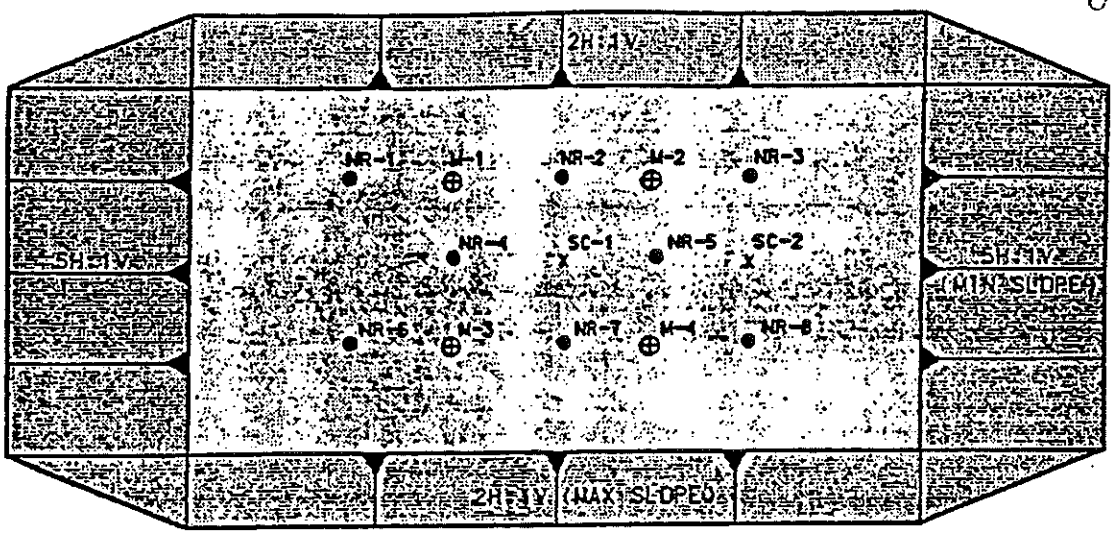
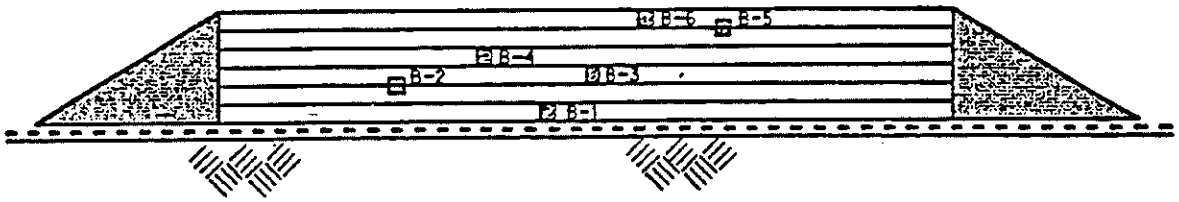


FIGURE 3 – EXAMPLE RELATIONSHIP BETWEEN DRY UNIT WEIGHT AND NUMBER OF COMPACTOR COVERAGES

000515





LEGEND

● NR-1	NUCLEAR GUAGE READING ON DENSITY AND MOISTURE (8 MIN/LIFT)
x SC-1	SAND CONE TEST (2 MIN/LIFT)
⊕ M-1	MOISTURE CONTENT SAMPLE (4 MIN/LIFT))
⊡ B-1	SHELBY TUBE OR BLOCK SAMPLE FOR LABORATORY TESTING (6 MIN PER TEST FILL AT VARYING DEPTHS)

FIGURE 4 – TYPICAL TEST SAMPLING CONFIGURATION

NTS

1.2.7 Geosynthetic Quality Assurance Consultant

1.2.7.1 *Definitions*

The Geosynthetic Quality Assurance Consultant (Geosynthetic QAC) is the firm which observes and documents activities related to the quality assurance of the production and installation of the geosynthetic components of the lining systems on behalf of the Owner. The Geosynthetic QAC and Soil QAC may be the same party.

In this QAM, the term Geosynthetic Quality Assurance Engineer (Geosynthetic QAE) shall be used to designate the engineer working for the Geosynthetic QAC in charge of the quality assurance work. In some cases the duties of the Geosynthetic QAE may be shared by two individuals: a Geosynthetic Quality Assurance Certifying Engineer and a Geosynthetic Quality Assurance Resident Engineer. Although not located at the site, the Geosynthetic Quality Assurance Certifying Engineer shall visit the site often enough to be familiar with the details of the project. The Geosynthetic Quality Assurance Certifying Engineer may also be known as the Geosynthetic Quality Assurance Officer.

The personnel of the Geosynthetic QAC also include Geosynthetic Quality Assurance Monitors who are located at the site for construction observation and documentation.

1.2.7.2 *Responsibilities*

The Geosynthetic QAC is responsible for observing and documenting activities related to the quality assurance of the production and installation of the geosynthetic components of the lining systems. The Geosynthetic QAC is responsible for implementation of the project QAP prepared by the Project Manager as well as reviewing work products of the Geosynthetic Quality Assurance Laboratory. The Geosynthetic QAC is also responsible for issuing a final Quality Assurance Report, sealed by a licensed Professional Engineer, as outlined in Section 2.0 of this QAM.

The specific duties of the Geosynthetic QAC personnel are as follows:

1. The Geosynthetic QAE:

   a. Familiarizes himself with all project plans and specifications.
   b. Reviews other site-specific documentation, including proposed layouts, and manufacturer's and installer's literature.
   c. Develops site-specific addenda for quality assurance of geosynthetics with the assistance of the Project Manager, as necessary.
   d. Administers the geosynthetic portions of the QAP, including assigning and managing all geosynthetic quality assurance personnel, reviewing all field reports, and providing engineering review of all quality assurance related issues.
   e. Reviews for familiarity all appropriate changes to design drawings and project specifications as issued by the Designer.
   f. Acts as the on-site (resident) representative of the Geosynthetic QAC.

g. Familiarizes all Geosynthetic Quality Assurance Monitors with the site and the project QAP.
h. Assigns Geosynthetic Quality Assurance personnel to observe and document geosynthetic installation activities requiring certification.
i. Attends all quality assurance related meetings, including resolution, pre-construction, daily, weekly.
j. Reviews all Manufacturer and Installer certifications and documentation and makes appropriate recommendations.
k. Reviews the Installer's personnel qualifications for conformance with those qualifications preapproved for work on site.
l. Manages the preparation of the record drawings.
m. Reviews the calibration certification of the on-site testing equipment, as required.
n. Reviews all Geosynthetic Quality Assurance Monitor's daily reports, logs and photographs.
o. Notes any on-site activities that could result in damage to the geosynthetics.
p. Reports to the Project Manager, and logs in the daily report, any relevant observations reported by the Geosynthetic Quality Assurance Monitors.
q. Prepares his own daily report.
r. Prepares a daily summary of the quantities estimates of geosynthetics installed that day.
s. Prepares the weekly summary of geosynthetic quality assurance activities.
t. Oversees the marking, packaging and shipping of all laboratory test samples.
u. Reviews the results of laboratory testing and makes appropriate recommendations.
v. Recommends the approval of the final liner acceptance to the Project Manager.
w. Designates a Geosynthetic Quality Assurance Monitor to represent the QAE whenever he is absent from the site while operations are ongoing.
x. Reports any unapproved deviations from the QAP immediately to the Project Manager.
y. Prepares the final Quality Assurance Report.

2. The Geosynthetic Quality Assurance Monitor:

a. Monitors, logs, photographs and/or documents all geosynthetic installation operations. Photographs shall be taken routinely and in critical areas of the installation. These duties shall be assigned by the Geosynthetic QAE.

b. Monitors the following operations for all geosynthetics:

(1) Material delivery
(2) Unloading and on-site transport and storage
(3) Sampling for conformance testing
(4) Deployment operations
(5) Joining and/or seaming operations
(6) Condition of panels as placed
(7) Visual inspection by walkover
(8) Repair operations

c. Monitors and documents the geomembrane seaming operations, including:

(1) Trial seams
(2) Seam preparation
(3) Seaming
(4) Nondestructive seam testing
(5) Sampling for destructive seam testing
(6) Field tensiometer testing
(7) Laboratory sample marking
(8) Repair operations
(9) Measurements of uninstalled quantities

d. Documents any on-site activities that could result in damage to the geosynthetics. Any problems noted shall be reported as soon as possible to the Geosynthetic QAE.

Any differences between the Geosynthetic QAC's and Installer's interpretation of the project plans and specifications shall be properly and adequately assessed by the Geosynthetic QAC. If such assessment indicates any actual or suspected work deficiencies, the Geosynthetic QAC shall inform the Installer, or the Installer's representative, of these deficiencies.

1.2.7.3 *Qualifications*

The Geosynthetic QAC shall be pre-qualified by the Owner. The Geosynthetic QAC shall be experienced in quality assurance of geosynthetics with emphasis on polyethylene geomembranes. The Geosynthetic QAC shall be experienced in the preparation of quality assurance documentation including quality assurance forms, reports, certifications, and manuals.

The Geosynthetic Quality Assurance Certifying Engineer shall hold a B.S., M.S. or Ph.D degree in civil engineering or related fields and be licensed as a Professional Engineer. If the duties of the Geosynthetic QAE are shared by two parties, only the Certifying Engineer shall be required to be licensed as a Professional Engineer. The Geosynthetic Quality Assurance Resident Engineer shall be specifically experienced in the installation of geosynthetics and shall be trained and certified by the Geosynthetic QAC in the duties of a Geosynthetic QAE. The Geosynthetic QAC shall be approved by the Project Manager.

Geosynthetic Quality Assurance Monitors shall be quality assurance personnel who have been specifically trained in the quality assurance of geosynthetics. The Monitors shall be approved by the Project Manager.

1.2.7.4 *Submittals*

Pre-qualification: At a minimum, the Geosynthetic QAC shall provide the following information in writing to the Project Manager to be considered for pre-qualification:

1. Corporate background and information.
   a. General company information
   b. Proof of insurance

(1) Professional liability
(2) "Umbrella" coverage
(3) Other coverages as required by statute and/or proposed contractual agreement

2. Quality assurance capabilities:
   a. A summary of the firm's experience with geosynthetics.
   b. A summary of the firm's experience in quality assurance, including installation quality assurance of geosynthetics.
   c. A summary of quality assurance documentation and methods used by the firm, including sample quality assurance forms, reports, certifications, and manuals prepared by the firm.
   d. Resumes of key personnel.

Additional information may need to be submitted if required by the Project Manager.

Pre-installation: Prior to beginning work on a project, the Geosynthetic QAC must provide the Project Manager with the following information:

1. Resumes of personnel to be involved in the project including Geosynthetic QAE and Geosynthetic Quality Assurance Monitors.
2. Proof of professional engineering registration in the appropriate state for the engineer to be designated as the Geosynthetic QAE, as well as proof of B.S., M.S., or Ph.D in civil engineering or related field degree.
3. Proof of the required quality assurance experience of all of the quality assurance personnel with emphasis on polyethylene geomembranes.
4. Examples of forms to be used in documentation of the project.

1.2.8 Soil Quality Assurance Laboratory

1.2.8.1 *Definitions*

The Soil Quality Assurance Laboratory (Soil QAL) is the firm which conducts tests on soil samples taken from the site. The Soil QAL and Geosynthetic QAL may be the same party.

1.2.8.2 *Responsibilities*

The Soil QAL is responsible for conducting the appropriate laboratory tests as directed by the Soil QAE. The test procedures shall be done in accordance with the test methods outlined in this QAM and/or the project QAP. The Soil QAL shall be responsible for providing tests results as outlined in Section 1.2.0.4.

1.2.8.3 *Qualifications*

The Soil QAL shall be pre-qualified by the Owner and approved by the Project Manager. The Soil QAL shall have properly maintained and periodically calibrated appropriate testing equipment. The Soil QAL shall also ensure that laboratory soil testing is performed by

personnel with experience and/or training in soil testing fundamentals. The laboratory personnel shall be familiar with American Society for Testing and Materials (ASTM), American Association of State Highway and Transportation Officials (AASHTO), Federal Test Method Standard (FTMS) and other applicable test standards. The Soil QAL shall be capable of providing test results within project deadlines throughout the soil prequalification and installation phase of the soil components.

The Soil QAL shall submit sample data and analysis to be used during the lab tests to the Project Manager.

1.2.8.4 *Submittals*

The Soil QAL shall submit all written test results within project deadlines to the Soil QAE. Soil test results shall be provided to the Soil QAE as soon as possible after test completion. Written test results shall be in an easily readable format and include references to the standard test methods used.

1.2.9 Geosynthetic Quality Assurance Laboratory

1.2.9.1 *Definitions*

The Geosynthetic Quality Assurance Laboratory (Geosynthetic QAL) is the firm which conducts tests on samples of geosynthetics taken from the site. The Geosynthetic QAL and the Soil QAL may be the same party.

1.2.9.2 *Responsibilities*

The Geosynthetic QAL is responsible for conducting the appropriate laboratory tests as directed by the Geosynthetic QAE. The test procedures shall be done in accordance with the test methods outlined in this QAM and/or the project QAP. The Geosynthetic QAL shall be responsible for providing test results as outlined in Section 1.2.9.4.

1.2.9.3 *Qualifications*

The Geosynthetic QAL shall be pre-qualified by the Owner and approved by the Project Manager. The Geosynthetic QAL shall have properly maintained and periodically calibrated appropriate testing equipment. The Geosynthetic QAL shall also ensure the laboratory testing is performed by personnel with experience and/or training in geosynthetic testing fundamentals.

The Geosynthetic QAL shall be familiar with ASTM, FTMS, National Sanitation Foundation (NSF), and other applicable test standards. The Geosynthetic QAL shall be capable of providing results of destructive seam tests within 24 hours of receipt of test samples and shall maintain that standard throughout the installation. On-site laboratory facilities may be used by the Geosynthetic QAL, provided they are appropriately equipped and approved by the Geosynthetic QAC and Project Manager.

1.2.9.4 *Submittals*

The Geosynthetic QAL shall submit all destructive seam test results to the Geosynthetic QAE in written form within 48 hours of receipt of test samples unless otherwise specified by the Project Manager. Geomembrane destructive test results shall typically be provided to the Geosynthetic QAE within 24 hours of receipt of test samples. Written test results shall be in an easily readable format and include references to the standard test methods used.

1.3 COMMUNICATION

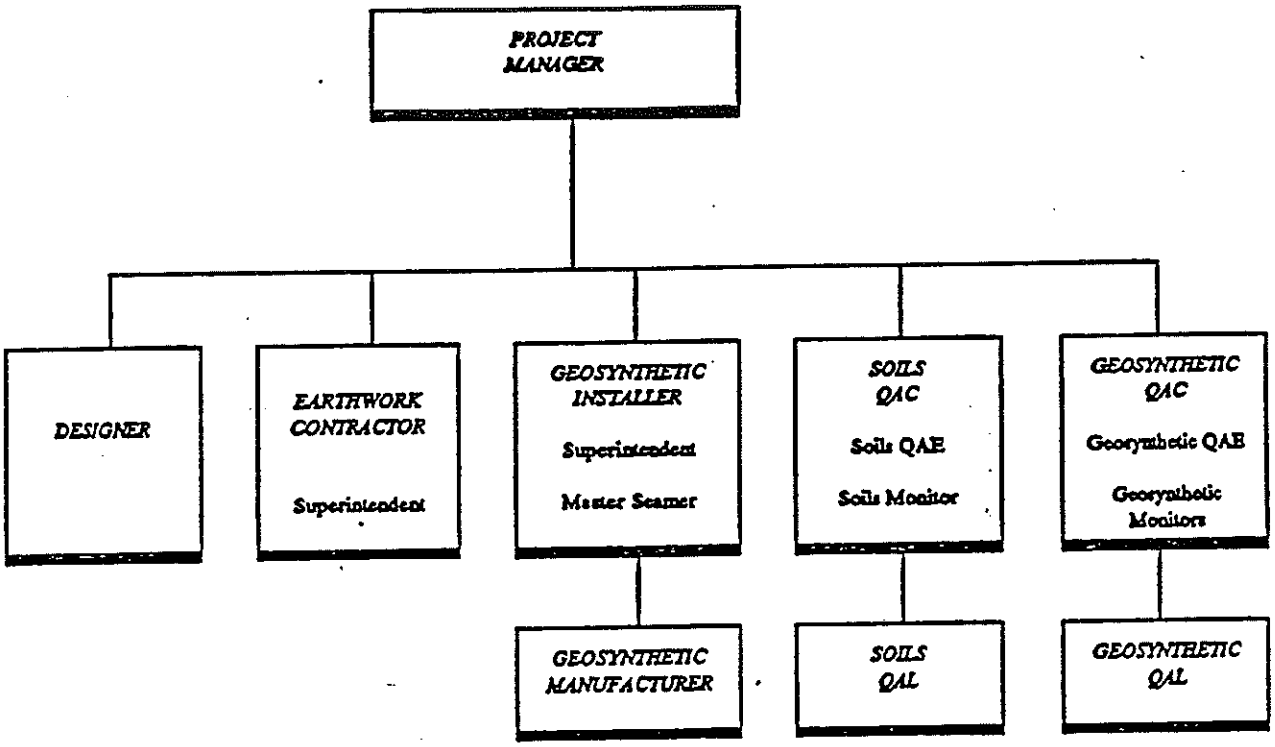
To help ensure a high degree of quality during installation and assure a final product that meets all project specifications, clear, open channels of communication are essential between all parties. This section discusses appropriate lines of communication and describes all meetings that will be necessary to achieve project goals.

1.3.1 Lines of Communication

The typical lines of communication necessary during a project are illustrated in Exhibit 1-1. The Soil QAE and Geosynthetic QAE shall be capable of direct communication with the Project Manager at all times.

Exhibit 1-1

LINES OF COMMUNICATION



1.3.2 Resolution Meeting

Following permit approval and the completion of the project plans and specifications, a resolution meeting may be held. If a Project Manager determines a resolution meeting is necessary, it shall be held prior to bidding the construction work and include all parties involved, typically including the Project Manager, Designer, Soil/Geosynthetic QAE and the Owner's technical representative. If appropriate, this meeting may be held in conjunction with the pre-bid meeting.

The purpose of the resolution meeting is to establish lines of communication, review project plans and specifications for completeness and clarity, begin planning for coordination of tasks, anticipate any problems which might cause difficulties and delays in construction, and complete the QAP. The design shall be discussed during this meeting so that clarification and/or design changes may be made before the construction work is bid. In addition, the guidelines regarding quality assurance testing and problem resolution must be known and accepted by all.

A recommended agenda for the resolution meeting is presented in Exhibit 1-2. The meeting shall be documented by a person designated at the beginning of the meeting, and minutes shall be transmitted to all parties.

1.3.3 Pre-Construction Meeting

A pre-construction meeting shall be held at the site prior to beginning of lining system installation. Typically, the meeting shall be attended by the Project Manager, Designer, Earthwork Contractor, Geosynthetic Installer, Soil/Geosynthetic QAE and the Owner's technical representative.

Specific topics considered for this pre-construction meeting include review of the project QAP for any problems or additions. The responsibilities of each party should also be reviewed and understood clearly. A recommended agenda with specific topics for the pre-construction meeting is presented in Exhibit 1-3. The meeting shall be documented by a person designated at the beginning of the meeting, and minutes shall be transmitted to all parties.

1.3.4 Progress Meetings

A weekly progress meeting shall be held between the Soil/Geosynthetic QAE, Earthwork Contractor's/Installer's Superintendent, Project Manager and any other concerned parties. This meeting shall discuss current progress, planned activities for the next week, issues requiring resolution, and any new business or revisions to the work. The Soil/Geosynthetic QAE shall log any problems, decisions, or questions arising at this meeting in his weekly report. If any matter remains unresolved at the end of this meeting, the Project Manager shall be responsible for the resolution of the matter and the communication of the decision to the appropriate parties. The Project Manager may require daily progress meetings at his discretion.

Exhibit 1-2
RESOLUTION MEETING AGENDA
EXAMPLE

1. Introductions

   A. Assign Minute Taker
   B. Identify Parties
      1. Project Manager
      2. Designer
      3. Soil/Geosynthetic Quality Assurance Consultant
      4. Owner technical representative
      5. Others

2. Tour Project Site

3. Review Documents

   A. Project Plans
   B. Project Specifications
   C. Construction Quality Assurance Manuals
   D. Permit Documents

4. Complete Quality Assurance Plan

   A. Project-specific Addendum to Quality Assurance Manual(s)
   B. Project-specific Addendum to project specifications

5. Discuss Contract Administration and Construction Issues

6. Define Lines of Communication

7. Define Project Deliverables

8. Determine Schedule

Exhibit 1-3
PRE-CONSTRUCTION MEETING AGENDA
EXAMPLE

1. Introductions

   A. Assign Minute Taker
   B. Identify Parties
      1. Project Manager
      2. Designer
      3. Surveyor
      4. Earthwork Contractor
      5. Geosynthetic Installer
      6. Soil/Geosynthetic Quality Assurance Consultant
      7. Soil/Geosynthetic Quality Assurance Laboratory
      8. Owner technical representative
      9. Others

2. Tour Project Site

3. Review Documents

   A. Project Plans
   B. Project Specifications
   C. Geosynthetic Panel Layout
   D. Project Quality Assurance Plan
   E. Health and Safety Plan

4. Define Lines of Communication

   A. Lines of Communication
   B. Reporting Methods
   C. Distribution Methods
   D. Progress Meetings
   E. Procedures for Approving Design Clarifications and Changes During Installation

5. Review Site Requirements

   A. Safety Rules
   B. Site Rules
   C. Work Schedule
   D. Storage of Materials
   E. Available Facilities

Exhibit 1-3 (Continued)
PRE-CONSTRUCTION MEETING AGENDA

6. Discuss Construction Issues

   A. Scope of Work
   B. Review Design
      1. Construction Drawings
      2. Specifications
      3. Geosynthetic Panel Layout
   C. Construction Procedures
      1. Proposed Construction Sequencing
      2. Location of Soil Stockpile Areas
      3. Location of Geosynthetic Storage Area
      4. Equipment
   D. Construction Schedule
   E. Procedures for Preparing and Approving Change Orders

7. Complete Construction Quality Assurance Plan

   A. Soils
   B. Geosynthetics
   C. Structural Systems (e.g., risers, piping, etc.)

8. Establish Project Deliverables

   A. Responsibilities
      1. Designer
      2. Installer
      3. Earthwork Contractor
      4. Soil/Geosynthetic Quality Assurance Consultant
      5. Soil/Geosynthetic Quality Assurance Laboratory
      6. Project Manager
   B. Distribution of Deliverables
   C. Approval Procedures

2.0 DOCUMENTATION

An effective QAP depends largely on identification of those construction activities that require monitoring, and on assigning responsibilities for the monitoring of each activity. This is most effectively verified by the thorough documentation of quality assurance activities. The Soil/Geosynthetic QAC shall document that all requirements in the lining portions of the project QAP have been addressed and satisfied.

The Soil/Geosynthetic QAC shall provide the Project Manager with signed descriptive remarks, data sheets, and checklists to verify that required monitoring activities have been carried out. The Soil/Geosynthetic QAC shall also maintain at the job site a complete file of all documents which comprise the QAP, including plans and specifications, this QAM, checklists, test procedures, daily logs, and other pertinent documents.

2.1 DAILY REPORTS

2.1.1 Soils Reports

Each Soil Quality Assurance Monitor shall complete a daily report and/or logs on prescribed forms outlining all monitoring activities for that day. The report at a minimum shall consist of field notes, observations, test data sheets, construction problems and solution data sheets. A summary of all supporting data sheets along with final testing results and Soils QAE's approval of the work shall be required upon completion of construction.

The Project Manager shall immediately be made aware of any nonconformance with the project specifications. In particular, the Project Manager shall be informed before the work in question is covered by overlying system layers. The Project Manager shall then determine its cause and recommend direct appropriate changes or recommend the appropriate changes. When this type of evaluation is made, the results shall be documented, and any revision to procedures or project specifications shall be approved in writing by the Owner and Designer.

2.1.2 Geosynthetic Reports

Each Geosynthetic Quality Assurance Monitor shall complete a daily report and/or logs on prescribed forms outlining all monitoring activities for that day. The precise areas worked on, panel numbers, seams completed and approved, measures taken to protect unfinished areas overnight and other appropriate data and information shall be identified. Failed seams, other panel areas, or other geosynthetics requiring remedial action shall be identified with regard to nature of action, required repair, and precise location. Repairs completed must also be identified. Any problems or concerns with regard to operations on site should be noted. The report should also include information regarding the weather conditions. This report must be completed at the end of each monitor's shift, prior to leaving the site, and submitted to the Geosynthetic QAC.

The Geosynthetic QAE shall review the daily reports submitted by the Quality Assurance Monitors, and incorporate a summary of their reports into the QAE's daily report. Any matters

requiring action by the Project Manager shall be identified. The report shall include a summary of the quantities of all material installed that day. This report must be completed daily, summarizing the previous day's activities, and a copy submitted to the Project Manager at the beginning of the work day following the report date.

2.2 TEST REPORTS

2.2.1 Soils Testing Reports

Records of field and laboratory testing performed on the soil components of the liner shall be collated by the Soil QAC. A summary list of test results shall be prepared by the Soil QAC on an ongoing basis, and submitted with the weekly progress reports.

2.2.2 Geosynthetic Testing Reports

The destructive test reports from all sources shall be collated by the Geosynthetic QAC. This includes field tests, Installer's laboratory tests (if performed), and Geosynthetic QAL tests. A summary list of test samples pass/fail results shall be prepared by the Geosynthetic QAC on an ongoing basis, and submitted with the weekly progress reports. The report shall also contain resolution on failed tests clearly documenting complete quality assurance conformance with established procedures.

2.3 PROGRESS REPORTS

Progress reports shall be prepared by the Soil and Geosynthetic QAEs and submitted to the Project Manager. These reports shall be submitted every week, starting the first Friday of soil placement or geosynthetics deployment on site or other day as approved by the Project Manager. This report shall include an overview of progress to date and an outline of any deviation from the project plans or specifications. The report shall also include any problems or deficiencies in installation at the site, an outline of any action taken to remedy the situation, a summary of weather conditions and a brief description of activities anticipated for the next reporting period. All daily reports for the period should be appended to each progress report.

2.4 RECORD DRAWINGS

2.4.1 Soils Drawings

Record drawings shall be prepared by the Soil QAC. The record drawings shall include, at a minimum, the following information for soil components:

1. Surveyed grade of the prepared subgrade.
2. Surveyed grade of the clay layer and other soil components.
3. Measured dimensions of any excavation within the subgrade and also within the soil layers.
4. Locations of all field tests and samples obtained for laboratory testing.
5. Locations of all repairs performed on soil components.
6. Locations of grade changes relative to site survey grid.

If necessary, for the purpose of clarity in the drawings, separate sheets shall be used to illustrate the locations of test sampling points. The drawings shall be shown in both plan and in cross section views as applicable. All surveying shall be performed by a licensed land surveyor.

2.4.2 Geosynthetic Drawings

Record drawings shall be prepared by the Geosynthetic QAC. The record drawings shall include, at a minimum, the following information for geomembranes:

1. Dimensions of all geomembrane field panels.
2. Location, as accurately as possible, of each panel relative to the site survey grid furnished by the Project Manager.
3. Identification of all seams and panels with appropriate numbers or identification codes.
4. Location of all patches and repairs.
5. Location of all destructive testing samples.

The record drawings shall illustrate each layer of geomembrane, and if necessary, other drawings shall identify problems or unusual conditions of the geotextile or geonet layers. In addition, applicable cross sections shall show layouts of geonets, geotextiles or geogrids in sump areas or any other areas which are unusual or differ from the design drawings. All surveying for as-built information shall be performed by a licensed land surveyor.

2.5 FINAL QUALITY ASSURANCE REPORT

Upon completion of the work, the Soil/Geosynthetic QAC shall submit a final Quality Assurance Report to the Project Manager. This report shall summarize the activities of the project, and document all aspects of the quality assurance program performed.

The final Quality Assurance Report shall include, at a minimum, the following information:

1. Parties and personnel involved with the project.
2. Scope of work.
3. Outline of project.
4. Quality assurance methods.
5. Test results (conformance, destructive and non-destructive, including laboratory tests).
6. Signature page, sealed and signed by a licensed Professional Engineer.
7. Record drawings, sealed and signed by a licensed Professional Engineer.

The Soils/Geosynthetic QAC shall state in the report that the installation has proceeded in accordance with the project QAP except as noted to the Project Manager. A recommended outline for the final Quality Assurance Report is given in Exhibit 2-1. The items shown in Exhibit 2-1 shall be considered the minimum content. The Soils/Geosynthetic QAC may expand the content as required.

Exhibit 2-1
FINAL CONSTRUCTION QUALITY ASSURANCE REPORT
GENERAL OUTLINE

1. Introduction

   A. Purpose
   B. Scope
   C. Unit Description
   D. Project Parties

2. Project QAP

   A. Scope
   B. Design Changes
   C. Project-Specific Addenda
   D. Permit Conditions
   E. Regulations

3. Work Performed

   A. Weather Constraints
   B. Pre-construction Testing
   C. Conformance Testing
   D. Visual Monitoring
   E. Photo Documentation
   F. Construction Testing
   G. Repairs

4. Summary and Conclusions

5. Project Certification

6. Appendices

   A. Geosynthetic and/or Soils QAC Personnel
   B. Contractor Personnel
   C. Quality Assurance Plan (QAP) with Project-Specific Addenda
   D. Design Change Forms
   E. Earthwork Testing Records (if required)
   F. Conformance Testing Records
   G. Manufacturer Quality Control Records